AN ASSESSMENT OF BIOLOGICAL INTEGRITY AND IMPAIRMENT OF AQUATIC LIFE IN THE CLARK FORK RIVER AND ITS MAJOR TRIBUTARIES BASED ON THE STRUCTURE AND COMPOSITION OF ALGAE ASSOCIATIONS IN THE PERIPHYTON COMMUNITY DURING AUGUST 1994

Erich E. Weber

*Phyco*Logic
East Helena, Montana

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SUMMARY

Periphyton (benthic algae) samples were collected by the Water Quality Division (WQD) of the Montana Department of Health and Environmental Sciences (now Department of Environmental Quality) from natural substrates at locations on the Clark Fork of the Columbia River and selected major tributaries for the purpose of assessing water quality, biological integrity, and overall impairment of aquatic life. Samples were collected at 25 locations in August 1994. Similar surveys have been conducted annually by the WQD since 1986.

Samples were analyzed for relative abundance of non-diatom genera, dominant non-diatom phylum, and relative abundance of diatom species. The total percent relative abundance of diatom species in three pollution tolerance groups were calculated. Diatom metrics calculated included: diatom species richness, Shannon diversity index, pollution index, siltation index and percent similarity index. Two protocols using specific criteria based on diatom metrics were used to assess biological integrity and overall impairment of aquatic life. Protocol I relied on least-impaired reference streams in Montana, while Protocol II utilized local upstream or sidestream reference sites for comparison.

Blacktail Creek, upstream of Silver Bow Creek, was found to have only fair biological integrity with moderate impairment of aquatic life, indicating somewhat impaired water quality. This was probably due to siltation related to historical mining activities, urbanization, and the naturally-occurring granitic geology.

Silver Bow Creek upstream from Butte's wastewater discharge had fair biological integrity, with moderate impairment of aquatic life, due to siltation and urban impacts. Silver Bow Creek from below the Colorado Tailings to downstream of the Warm Springs Ponds continued to exhibit poor biological integrity with severe overall impairment of aquatic life, indicating very poor water quality. Elevated heavy metals and nutrients from historical and municipal sources were suspected as the principal pollutants.

Warm Springs Creek had excellent biological integrity with no impairment of aquatic life, indicating very high water quality in this important headwater tributary to the Clark Fork.

Biological integrity at mainstem Clark Fork stations from Warm Springs Creek downstream to the Little Blackfoot River fluctuated between fair and good, with minor to moderate impairment of aquatic life, indicating generally good water quality with moderate impacts related to deposited sediment.

In the Clark Fork reach downstream of the Little Blackfoot River to above Missoula, biological integrity was good, with only minor impairment of aquatic life. Relatively high-quality water from the Little Blackfoot River, Rock Creek, and particularly the Blackfoot River, as indicated by favorable bioassessments for these tributary streams, likely had a positive effect on water quality in the middle reaches of the Clark Fork.

The Clark Fork downstream of the Missoula metropolitan area and the municipal wastewater treatment plant (WWTP) discharge had only fair biological integrity with a moderate level of aquatic life impairment. Biological integrity in the lower Bitterroot River was rated as good to excellent, with little or no aquatic life impairment. This was a major improvement over the relatively severe impairment seen in 1993, and apparently was due to much lower levels of nutrients and deposited sediment.

The Clark Fork at Harper Bridge had only fair biological integrity, with moderate impairment of aquatic life, apparently due to the somewhat impaired water quality below Missoula, with very little positive benefit attributable to

the Bitterroot River. This suggests a downstream lag before nutrients from the Missoula WWTP exert an effect on the Clark Fork biota.

Water quality in the Clark Fork at Huson and near Superior was slightly to moderately improved over the Clark Fork reach just below Missoula, with good biological integrity and only minor impairment of aquatic life at these sites. The Clark Fork station between Superior and the Flathead River was rated as having excellent biological integrity, with no impairment of aquatic life, while the Clark Fork downstream of the Flathead River had good biological integrity, indicating good to excellent water quality in the lower reaches of the Clark Fork in 1994 despite low streamflows.

Based on pollution index values and bioassessment Protocol I results, the trend over the period 1991-94 at Silver Bow Creek stations upstream of the Warm Springs Ponds was one of continued poor water quality, particularly at the stations immediately downstream of the Butte Metro WWTP and upstream of the ponds. Water quality fluctuated in Blacktail Creek and in Silver Bow Creek downstream of the Warm Springs Ponds, with somewhat of a downward trend evident. Warm Springs Creek had consistently high water quality. Over the same period, water quality was somewhat variable at Clark Fork stations downstream of Warm Springs Ponds to above the Little Blackfoot River. Water quality was relatively stable or somewhat improved at Clark Fork stations between Deer Lodge and Bonita over the four year period. High quality water from Rock Creek and the Blackfoot River had a positive influence on the Clark Fork at Turah and above Missoula, contributing to consistently high biological integrity over the four year period.

The trend at nearly all Clark Fork stations below Missoula, at least as far downstream as Superior, was for a slight decline in water quality since 1991. The Clark Fork station downstream of Missoula's WWTP, as well as at Harper Bridge and at Huson displayed weak downward trends, with slight decreases in biological integrity suggesting lower water quality. However, conditions at these stations may have stabilized somewhat in 1994. A similar, but more serious decline in water quality seen in the lower Bitterroot River over several years was reversed in 1994, suggesting much improved water quality. At the Clark Fork stations near Superior, as well as above and below the confluence with the Flathead River, water quality and biological integrity remained relatively high over the years 1991-94.

INTRODUCTION

In August of 1994, the Water Quality Division (WQD) of the Montana Department of Health and Environmental Sciences (DHES) (now Department of Environmental Quality) conducted benthic algae surveys at 25 sites on the Clark Fork of the Columbia River and several tributaries as part of their ongoing Clark Fork Basin Monitoring Project. Similar surveys have been conducted annually by WQD since 1986 (Bahls 1987 and 1989; Weber 1991, 1993 and 1994).

This report presents the results of the taxonomic analysis of periphyton samples collected during the 1994 surveys, and uses these data to assess water quality and biological integrity at the stream sites surveyed. Trends in water quality and biological integrity are evaluated through comparisons with monitoring results from previous years. Bahls (1993) states: "The concept of biological integrity is the basis for biological assessment and the setting of ecological goals for water quality." As defined by Karr and Dudley (1981): "Biological integrity is the ability of an aquatic ecosystem to support and maintain a ... community of organisms having species composition, diversity, and functional organization comparable to that of the natural habitats within a region." **This definition makes the explicit assumption that natural, undisturbed systems are better than those affected by human activities.**

Periphyton is the assemblage of small, often microscopic organisms (microinvertebrates, bacteria, fungi, and benthic algae) that live attached to or in close association with the surfaces of submerged substrates. Benthic algae typically dominate the periphyton community in most waters. They can be conveniently divided into two major groups: the diatoms and the non-diatoms, by the presence or absence of a rigid, siliceous cell wall. The taxonomy of both groups has been well established; diatoms, however, are readily identifiable to species because of uniquely ornamented cell walls, while it is much more difficult, and therefore generally impractical, to identify non-diatom algae below the genus level.

Algae, and particularly the diatoms, are useful as biomonitors of water quality because they occur in very large numbers, are highly sensitive to physical and chemical factors, and have known environmental requirements and pollution tolerances unique to individual species (Bahls 1989). Plafkin et al. (1989) lists several other advantages of using algae for bioassessment:

1. Algae generally have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts. (Perennial and fossil algae, including expired but recognizable algae incorporated into the periphyton matrix, reflect longer term impacts).

2. As primary producers, algae are most directly affected by physical and chemical factors.

3. Sampling is easy, inexpensive, requires few people, and creates minimal impact to resident biota.

4. Relatively standard methods exist for evaluation of functional and non-taxonomic structural characteristics (e.g., biomass and chlorophyll) of algal communities.

5. Algal communities are sensitive to some pollutants which may not visibly affect other aquatic communities such as macroinvertebrates or fish, or may only affect other communities at higher concentrations (e.g., herbicides and inorganic nutrients).

Generally, the algae present in a periphyton sample reflect the environmental conditions that existed at a particular stream location for up to several weeks prior to the time of sample collection. However, many factors in addition to water quality can affect the types and amount of algae present at any given time. These include, but are not necessarily limited to, very low or very high streamflows, variable recolonization rates, seasonal succession, and sloughing of accumulated algae. By allowing adequate time for substrate recolonization following the spring spate, by sampling before major sloughing of algal biomass occurs in late summer and early fall, and by sampling at the same time each year, the effects of factors unrelated to water quality can be minimized. Monitoring conducted during the first half of August probably best meets the aforementioned criteria. Additionally, it likely encompasses the period of poorest seasonal water quality and maximum environmental stress on stream biota due to low streamflows, elevated water temperatures, and minimum instream dilution of pollutants and wastewater discharges.

METHODS

WQD personnel collected composite periphyton samples from natural substrates at 25 monitoring stations on the Clark Fork and selected tributaries in 1994 (Table 1 and Figure 1). The 25 stations were identical to those monitored in 1993, when seven new stations were established to replace stations altered or eliminated by Superfund remedial activities or to better meet monitoring needs (Weber 1994).

Sampling was conducted from August 15 through August 19, 1994. Periphyton samples were collected using methods in section 4.1.2.3 (Sampling) of the Water Quality Division's Field Procedure Manual (DEQ, revised 1996): "Macroalgae are collected from natural substrates in proportion to the rank of those substrates at the study site as recorded on the Aquatic Plant Field Sheet. Collection of microalgae typically involves scraping the entire surface of several rocks, lifting the algal film off of nearshore sediments, and scraping a submerged branch or two. Macroalgae are picked by hand in proportion to their abundance at the site. In selecting macroalgae for sampling, the sampler tries to visually distinguish between the various growth forms that represent different algal taxa. Macroalgae are collected both for determining community composition and as substrates for microalgae. The goal is to collect a single composite sample that is a miniature replica of the stand of algae that is present at the study site. All collections of microalgae and macroalgae are pooled into a common sample container. Enough ambient water should be added to the container to cover the sample. Then enough iodine potassium iodide (Lugol's Solution) should be added to impart a light brown tint to the sample. The purpose of the Lugol's solution is to retard bacterial decay."

Each sample was processed and analyzed by PhycoLogic in the following manner: A subsample of the periphyton from each station was examined using an Olympus BHT compound microscope at 200X and 400X magnifications, and all soft bodied (non-diatom) algae present were identified to genus. The relative abundance of cells belonging to each genus was estimated using the following system:

- R (Rare): Fewer than one cell per microscope field at 200X, on the average;

- C (Common): At least one, but fewer than five cells per field of view;

- VC (Very Common): Between 5 and 25 cells per field of view;

- A (Abundant): Greater than 25 cells per field of view, but numbers within limits reasonably counted;

- VA (Very Abundant): Number of cells per field too numerous to count.

The abundance of diatom algae (all genera collectively) relative to the non-diatom genera also was estimated for comparative purposes.

Each dominant non-diatom genus (i.e., each genus common or greater in relative abundance), as well as the diatom component if it met this criterion, also was ranked according to its estimated contribution to the total algal biovolume present in the sample. The genus contributing the greatest biovolume was ranked number 1, the second most number 2, and so on. These rankings were used to calculate the dominant non-diatom phylum (see Non-Diatom Algae Metrics, below).

Following analysis of non-diatom algae, all organic matter was chemically oxidized from each sample, leaving only the siliceous cell walls (frustules) of diatoms and other inorganic matter. Permanent strewn mounts of the cleaned diatom material were prepared on glass microscope slides with Hyrax medium according to procedure 10200D.3 in Standard Methods (APHA et al. 1992). Each permanent mount was thoroughly scanned under 1000X oil immersion, and all diatoms encountered identified to species. A proportional count of approximately 400 diatom frustules (range 405-438, mean 420) was performed on each permanent mount, and the percent relative abundance (PRA) of each diatom species was calculated. Diatom species identified during the floristic scan but not tallied during the proportional count were designated as "present" with a letter "p".

Each diatom species was assigned to one of the three pollution tolerance (PT) groups originally defined by Lange-Bertalot (1979). Simply stated, Group 1 taxa are most tolerant of pollution, Group 2 taxa less tolerant, and Group 3 sensitive to pollution. Bahls (1993) published expanded autecological criteria for assigning diatom taxa to PT groups, along with an extensive listing of diatom taxa reported from Montana. He also determined default PT group assignments, by genus, for taxa lacking sufficient autecological data. A number of unlisted taxa were assigned to PT groups by this author, based on updated autecological data in references by Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b) and Lange-Bertalot (1993). Default PT group assignments were used as a last resort.

In establishing the autecological criteria used to assign a diatom taxon to one of the three pollution tolerance groups, Bahls (1993) considered seven ecological variables: algal nutrients, organic (biogenic) pollutants, salts, temperature, toxics, substrate type, and suspended solids. A taxon is assigned to the group which fits most of the ecological affinities for that taxon.

Table 1. Periphyton sampling locations on the Clark Fork of the Columbia River and tributaries during August 1994.

Station	Site Description
SF-1	Blacktail Creek (BTC) above Grove Gulch
00	Silver Bow Creek (SBC) above Butte Metro Wastewater Treatment Plant (WWTP)
01	SBC below Colorado Tailings (and below Butte Metro WWTP)
2.5	SBC at Opportunity
4.5	SBC below Warm Springs Ponds
06	Warm Springs Creek (WSC) near mouth
07	Clark Fork (CFR) below Warm Springs Creek
09	CFR at Deer Lodge
10	CFR above Little Blackfoot River
10.2	Little Blackfoot River (LBR) near mouth
11	CFR at Gold Creek Bridge
11.5	Flint Creek (FTC) at New Chicago
11.7	CFR at Bearmouth
12	CFR at Bonita
12.5	Rock Creek (RKC) near Clinton
13	CFR at Turah
14	Blackfoot River (BFR) at USGS Station near mouth
15.5	CFR above Missoula
18	CFR at Shuffields (and below Missoula WWTP)
19	Bitterroot River (BRR) near mouth
20	CFR at Harper Bridge
22	CFR at Huson (and below Stone Container Corporation)
24	CFR near Superior
25	CFR above Flathead River
27	CFR above Thompson Falls Reservoir

Non-Diatom Algae Metrics

Metrics applied to soft-bodied or non-diatom algae at each station include: **number of dominant genera; dominant phylum**; and, to a lesser extent, **indicator taxa**.

The **number of dominant non-diatom genera** is generally inversely proportional to the degree of pollution in western Montana streams. For least-impaired reference streams in mountain ecoregions in Montana, which included mountain valleys and foothills, Bahls (1993) reported from 1 to 10 non-diatom genera common or greater in relative abundance, with a mean value of 5. In pristine waters, low numbers of non-diatom genera generally indicate nutrient-poor conditions, which are usually directly related to the mineral make-up of rock in the drainage area. The presence of higher numbers of genera in unimpaired streams suggest naturally higher levels of algal nutrients, again primarily due to geology.

The **dominant non-diatom phylum** was determined by calculating the cumulative weighted rank of genera within each phylum based on estimated biovolume. Diatoms were not included in this metric. Briefly, in a sample with x number of non-diatom genera common or greater in estimated abundance, the genus ranking highest in estimated biovolume scored x points, second highest, x-1 points, and so on. The scores of all genera in each phylum were summed for each site, and the phylum having the greatest total score was considered dominant, based on estimated relative biovolume. Green algae (phylum Chlorophyta) generally do best where the concentration of available nitrogen is sufficiently high relative to available phosphorus. Where nitrogen is in relatively short supply, blue-green algae (phylum Cyanophyta) generally increase in abundance due to the fact that many of the Cyanophyta have the ability to "fix" atmospheric nitrogen, and thereby are better able to utilize the higher levels of available phosphorus. Bahls et al. (1992) found that blue-green algae dominated the non-diatom flora of Northern Rockies reference streams, while green algae were co-dominant with blue-green algae in streams of the Montana Valley and Foothill Prairies ecoregion. The Clark Fork mainstem is considered to be primarily in the Montana Valley and Foothill Prairies ecoregion, as are the main reaches of tributary streams included in this monitoring.

Diatom Metrics

Metrics calculated for diatom associations at each station include **species richness** (number of species counted); the percent relative abundance (PRA) of the **dominant taxon; Shannon diversity index**; and **siltation index**. The total PRA of species in each of the three **pollution tolerance (PT) groups** (see Methods), and their derivative, the pollution index, were also calculated.

Species richness is probably the most basic indicator of community health and, as a rule, is directly correlated to water quality: as water quality declines, so does the number of species. In general, unpolluted waters in Montana have more than 25 diatom species counted (Bahls 1979). In reference streams from mountain ecoregions in Montana, between 23 and 51 (mean 33) diatom species were counted (Bahls et al. 1992).

The **Shannon diversity index** (Weber 1973) incorporates elements of species richness with equitability, the evenness of distribution of individuals among the species present. High diversity values occur in diatom communities where no taxa are strongly dominant in numbers, which is generally the case in healthy, unimpaired streams. Diatom communities under environmental stress will have a relatively small number of taxa that account for most of the individuals present, resulting in lower diversity index values. In general, unpolluted waters in Montana have Shannon diversity values greater than 3.00 (Bahls 1979). Diatom

species diversity values of between 2.16 and 4.50 were found in 21 least-impaired reference streams from mountain ecoregions, with a mean value of 3.58 (Bahls 1993).

The **pollution index** was proposed by Bahls (1993) as a shorthand method of summarizing the information contained in the three pollution tolerance groups of Lange-Bertalot (1979). The index is derived from the decimal fraction of the total PRA value of diatom taxa in each pollution tolerance group, multiplied by the respective group number. The sum of these three products is the pollution index. The index will range from 1.00 (all most tolerant taxa) to 3.00 (all most sensitive taxa). Pollution index values of between 2.45 and 2.94 (mean 2.72) were determined by Bahls (1993) for diatom communities in reference streams from mountain ecoregions.

The **siltation index** is defined as the total percent relative abundance of species of *Navicula*, *Nitzschia* and *Surirella* diatoms present in a sample (Bahls 1993). These genera are considered because they are highly motile, biraphidean diatoms, and as such are better adapted to existence on unstable substrates. Values can range from 0 to 100; in mountain reference streams the index ranged from 0.0 to 50.3 (mean 14.5).

The percentage **similarity index** of Whittaker and Fairbanks (1958) is simply the sum of the smaller of the two percent relative abundance values for each diatom species that is common to both the control site and the study site. (Species restricted to one or the other site are not tallied because the smaller of the two values will always be zero.) Theoretically, values for this index will range from 0.0 (totally different communities) to 100 (identical communities). This index should be used only with Protocol II because of the high floristic variability among regional reference sites (Bahls 1993).

Assessment Protocols

Two protocols employing diatom metrics to assess biological integrity and aquatic life impairment in Montana streams were proposed by Bahls (1993):

Protocol I is used when a local reference or control site is not available, and compares the Shannon diversity index, pollution index, and siltation index values from a **study site** to values from least-impaired reference streams located in the same physiographic province, or "ecoregion". Protocol I was developed with, and should only be used with, data collected during the summer months.

Under Protocol I, each index is given an individual rating and assigned a score based on the value of that index in relation to a set of criteria (Table 5). Protocol I criteria for mountain streams were developed with data from 21 reference streams in the Northern Rockies, Middle Rockies, and the Montana Valley and Foothill Prairies ecoregions (Bahls et al. 1992). The criteria correspond to varying levels of environmental stress, pollution and siltation. The **lowest** score determines the overall biological integrity and impairment rating for the aquatic community at that station.

Protocol II compares diatom metrics values from a **study site** to values from a local upstream or sidestream **reference site**, sampled at the same time. The reference site should be of the same stream order as the study site. The three diatom metrics used in Protocol I, plus the percent similarity index of Whittaker and Fairbanks (1958), are used with Protocol II. Criteria used to establish impairment ratings and scores are contained in Table 14. Again, the **lowest** score establishes the overall biological integrity and impairment rating. Because it compares against local reference conditions, **Protocol II is probably more sensitive than Protocol I, but only if the local control site is not impaired and closely represents the biological potential for the study site.** Protocol II can be applied to data collected at any time during the year.

RESULTS AND DISCUSSION

Instream conditions throughout the Clark Fork Basin during the summer 1994 monitoring period once again departed significantly from the "norm", or average, expected for mid-August. Well below average precipitation during the spring and summer of 1994 resulted in very low streamflows during the monitoring period. Monthly mean streamflows for select USGS gaging stations in the Clark Fork Basin during August of nine consecutive years are presented in Table 2. The low flows during 1994 are comparable to previous drought years, particularly 1988, 1991 and 1992. The year 1994 stands in sharp contrast to 1993, when record or near-record precipitation throughout July and into mid-August resulted in well above average streamflows throughout the Clark Fork Basin during the monitoring period. The low streamflows during 1994 more than likely had direct or indirect effects on the structure, composition and productivity of the periphyton community due to many possible factors. These include, but are not necessarily limited to: elevated water temperatures; lower dissolved oxygen levels; increased incident sunlight levels; higher concentrations of algal nutrients and various other pollutants due to lower instream dilution of wastewater discharges; reduced loads of suspended sediment and sediment-bound toxic metals; and reduced flushing of deposited sediment due to decreased velocities.

Table 2. August monthly mean streamflows for selected USGS gaging stations in the Clark Fork Basin for the years 1986-1994. All flows in cubic feet per second.

Year	Silver Bow Creek Below Blacktail Creek USGS # 12323250	Clark Fork River at Deer Lodge USGS # 12324200	Clark Fork River below Missoula USGS # 12353000	Clark Fork River Near Plains USGS # 12389000
1986	19.5	55.7	1812	7612
1987	27.7	88.5	1473	9813
1988	18.7	27.8	997	5656
1989	22.0	81.7	2464	14750
1990	25.8	84.3	2554	10510
1991	16.4	30.1	1997	10350
1992	14.2	40.1	1280	9738
1993	28.7	312	3696	11770
1994	16.1	36.3	1295	5891

The 25 monitoring stations sampled in 1994 are divided into five groups of five stations to aid in interpretation and discussion, and are presented in order from upstream to downstream. Breakpoints for each group of five stations conveniently occur at tributary streams, and effectively divide the entire drainage into five logical reaches. Tables and figures containing the 1994 monitoring results are organized into this reach format whenever possible. The same format was used to present the 1993 Clark Fork Basin periphyton monitoring data (Weber 1994).

Non-Diatom Algae

The genera of non-diatom algae identified at each of the Clark Fork and tributary stations in 1994 are listed by phylum in Appendix A, along with estimated relative abundance and biovolume contribution rankings. Diatoms (all genera considered collectively) are included for comparison. The number of

dominant non-diatom genera (those common or greater in estimated relative abundance) and the dominant phylum (based on estimated biovolume; see Methods) are presented in Table 3. Numbers of dominant non-diatom genera, broken down by phylum as green, blue-green and "other" (yellow-green, brown and red) algae are plotted in Figures 2-6.

The number of dominant non-diatom algal genera present at the 25 Clark Fork and tributary stations monitored in 1994 ranged from 2 to 13, with a mean of slightly more than 9. Only two stations had fewer than 5 non-diatom genera present (Table 3; Figures 2-6).

The green algae (phylum Chlorophyta) were dominant at 19 of the 25 stations monitored in 1994, while blue-green algae (phylum Cyanophyta) were dominant at the 6 remaining stations (Table 3). Blue-green algae, however, were also relatively important at a majority of the stations where green algae were dominant, and vice versa, and the two phyla were essentially co-dominant at many of the stations (Appendix A).

A diverse assemblage of non-diatom algae comprising 10 dominant genera was present in Blacktail Creek above Grove Gulch (station SF-1) in August 1994. All but one of these genera are green algae, while none are blue-green algae (Figure 2). Most of the genera identified at station SF-1 are indicative of relatively good water quality. These include the filamentous green algae *Cladophora, Microspora, Oedogonium, Rhizoclonium* and *Spirogyra*, the desmid *Closterium,* and the filamentous yellow-green alga *Vaucheria*. These taxa do well in waters with low to moderate levels of inorganic nutrients, but are sensitive to organic (biogenic) pollution and heavy metals.

The number of dominant taxa decreased to 5 at Silver Bow Creek station 00 above the Butte Metro Wastewater Treatment Plant (WWTP), and to only 2 at station 01 below the WWTP and the Colorado Tailings deposit (Figure 2). At Silver Bow Creek station 2.5 at Opportunity, the number of dominant taxa increased slightly, to 4.

Virtually none of the top seven non-diatom taxa identified in Blacktail Creek during August 1994 were present in upper Silver Bow Creek at stations 00, 01 and 2.5 (Appendix A). The filamentous green alga *Stigeoclonium*, a taxon considered tolerant of both biogenic enrichment and heavy metals pollution, was a dominant form at both Silver Bow Creek stations 00 and 01, while the pollution-tolerant green algae *Cosmarium* and *Scenedesmus* were strongly dominant at station 2.5 (Appendix A). The genus *Oscillatoria* was the lone blue-green alga at station 00, while blue-greens were completely absent from station 01. *Oscillatoria* and a similar genus, *Phormidium,* again were dominant taxa at station 2.5 (Appendix A). Both *Oscillatoria* and *Phormidium* are somewhat ubiquitous genera containing numerous species that cover a broad range of pollution tolerances.

The number of non-diatom taxa at Silver Bow Creek stations 00, 01, and 2.5 decreased significantly compared to upstream station SF-1 on Blacktail Creek (Table 3). Additionally, pollution-sensitive forms present at SF-1 were replaced by pollution-tolerant taxa at the Silver Bow Creek stations. This suggests a worsening of water quality in Silver Bow Creek with distance downstream of its Blacktail Creek headwaters, to just above the Warm Springs Ponds during August 1994. The very low streamflows in 1994 would have provided for only minimum dilution of wastewater from the Butte Metro WWTP and other pollution sources to Silver Bow Creek.

At Silver Bow Creek station 4.5 below the Warm Springs Ponds, the number of dominant non-diatom taxa increased significantly, to 8 (Figure 2). The filamentous green algae *Cladophora* and *Oedogonium*, both relatively important at Blacktail Creek station SF-1, once again were strongly dominant at Silver Bow Creek station 4.5, while both blue-green genera seen at station 2.5 also were present below the Warm Springs Ponds (Appendix A).

Table 3. Summary of results for non-diatom and diatom algae in periphyton samples from the Clark Fork and tributaries during August 1994.

Station	Non-diatom Algae No. Dom. Taxa[a]	Non-diatom Algae Dominant Phylum[b]	Diatom Species Richness	Dominant Diatom Taxon[c]	PRA
SF-1	10	Chlorophyta	42	*Nitzschia fonticola*	13.25
00	5	Chlorophyta	21	*Achnanthes minutissima*	36.30
01	2	Chlorophyta	14	*Navicula minima*	46.35
2.5	4	Chlorophyta	13	*Navicula minima*	53.27
4.5	8	Chlorophyta	38	*Navicula minima*	20.53
06	8	Chlorophyta	38	*Cymbella affinis*	19.38
07	5	Chlorophyta	36	*Nitzschia paleacea*	13.91
09	10	Chlorophyta	38	*Achnanthes minutissima*	38.68
10	13	Chlorophyta	35	*Nitzschia inconspicua*	12.35
10.2	12	Chlorophyta	35	*Cocconeis placentula*	14.80
11	11	Chlorophyta	42	*Epithemia sorex*	27.51
11.5	9	Cyanophyta	43	*Navicula capitatoradiata*	12.71
11.7	12	Cyanophyta	39	*Epithemia sorex*	35.14
12	10	Cyanophyta	36	*Epithemia sorex*	40.14
12.5	10	Cyanophyta	37	*Fragilaria construens*	14.08
13	8	Cyanophyta	37	*Epithemia sorex*	22.76
14	11	Chlorophyta	37	*Cymbella affinis*	24.70
15.5	13	Chlorophyta	40	*Cymbella affinis*	14.76
18	8	Chlorophyta	34	*Cymbella affinis*	29.69
19	10	Chlorophyta	37	*Cymbella affinis*	19.34
20	9	Chlorophyta	35	*Cymbella affinis*	26.43
22	11	Chlorophyta	36	*Cymbella affinis*	19.95
24	8	Chlorophyta	35	*Cymbella affinis*	16.82
25	10	Cyanophyta	29	*Cyclotella meneghiniana*	42.48
27	12	Chlorophyta	41	*Cyclotella meneghiniana*	29.52

[a]Dominant taxa are defined as those common or greater in estimated relative abundance; see Appendix A.

[b]Dominant non-diatom phylum based on total estimated biovolume contribution of all dominant genera in each phylum; see Methods.

[c]Taxon with greatest Percent Relative Abundance (PRA) value; see last column.

Figure 2.

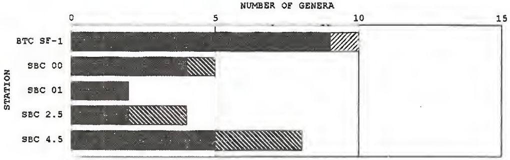


Figure 3.

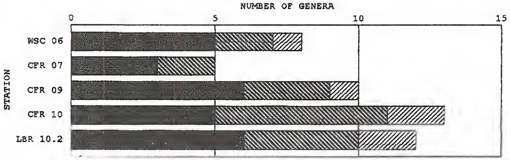


Figure 4.

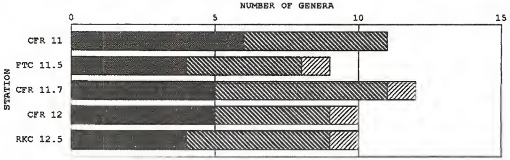


Figure 5.

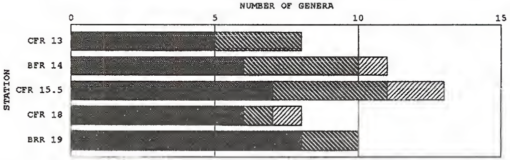
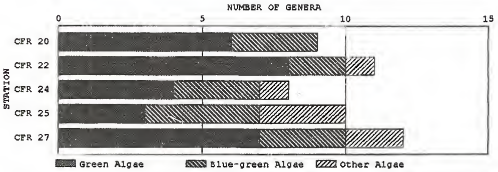


Figure 6.



Figures 2-6. Number of dominant non-diatom genera at Clark Fork and tributary stations during August 1994.

An increase in the number of dominant taxa and a shift to more pollution-sensitive forms at Silver Bow Creek station 4.5 suggest improved water quality immediately downstream of the Warm Springs Ponds over that seen upstream of the pond system. This apparent improvement at station 4.5 may reflect chemical and biological processes at work in the Warm Springs Ponds that can significantly reduce concentrations of heavy metals in Silver Bow Creek below the ponds. Additionally, Mill and Willow creeks may have contributed higher-quality water to Silver Bow Creek between stations 2.5 and 4.5.

Eight dominant non-diatom taxa were identified at Warm Springs Creek station 06 in August 1994 (Figure 3). Several pollution-sensitive genera were present, including the blue-green alga *Nostoc*, the red alga (phylum Rhodophyta) *Audouinella*, and the green algae *Oedogonium* and *Closterium* (Appendix A). At Clark Fork station 07, located immediately downstream of the confluence of Silver Bow Creek and Warm Springs Creek, only 5 dominant non-diatom taxa were present, three fewer than at either tributary (Figures 2 and 3). As might be expected, all of the dominant algae present at station 07 were also identified in Warm Springs Creek and/or Silver Bow Creek, although a few taxa that were relatively important in one or both tributaries were absent below the confluence. The relatively sensitive blue-green alga *Nostoc* from Warm Springs Creek, and the more tolerant and nearly ubiquitous green alga *Cladophora* from Silver Bow Creek were both strongly dominant at station 07, rating first and second, respectively, in relative biovolume (Appendix A). Interestingly, *Cladophora* and *Nostoc* would remain the top two non-diatom taxa, based on relative biovolume, at all Clark Fork stations downstream to the Blackfoot River (Appendix A). Although pollution sensitive non-diatom genera were present at Clark Fork station 07, the decrease in number of dominant taxa suggests that the biota may have been under some stress. This may have been due to higher water temperatures or changes in water chemistry caused by the abnormally low streamflows seen in 1994, which could result in a less-stable instream environment than was present in either of the tributary streams. Alternatively, Superfund remedial efforts in this reach could have caused some physical instability, such as siltation, that may have reduced non-diatom taxa at station 07.

At Clark Fork station 09 at Deer Lodge, the number of dominant non-diatom genera increased to 10, double the number present at station 07, while 13 taxa were identified at Clark Fork station 10 above the Little Blackfoot River (Figure 3). The blue-green alga *Nostoc* and the green alga *Cladophora* were again the most important non-diatom taxa at both stations 09 and 10. The pollution-tolerant green alga *Stigeoclonium* and the sensitive red alga *Audouinella* were both abundant at station 09. At station 10, the relatively sensitive yellow-green alga *Vaucheria* was a dominant form along with *Audouinella*, while *Stigeoclonium* was nearly absent (Appendix A). Blue-green algae became much more important at station 10, with 6 dominant genera present, two of which were not found at upstream stations (Figure 3; Appendix A). The trend in the Clark Fork reach between Warm Springs Creek and the Little Blackfoot River in August 1994, based on the number and types of algae present, appears to have been one of improving water quality. Because of the lack of dilution due to very low streamflows in 1994, levels of available algal nutrients in the Clark Fork probably were relatively high, largely from point source discharges of treated wastewater at Warm Springs State Hospital, Galen and Deer Lodge. Concentrations of toxic metals would have been relatively low due to reduced erosion of stream bank and stream channel sediments. The low, stable instream conditions, adequate nutrients and reduced metals inputs allowed algal diversity and productivity to be relatively high.

Biological conditions in the Little Blackfoot River at station 10.2 were very similar to the Clark Fork at station 10, with 12 dominant non-diatom algae present (Figure 3). The two stations had several taxa in common, including the relatively sensitive genera *Audouinella*, *Nostoc*, and *Vaucheria*. However, in the Little Blackfoot River *Vaucheria* was much more important in relative abundance and biovolume than in the Clark Fork, and the filamentous green alga *Cladophora*

was completely absent (Appendix A). The non-diatom algae present at station 10.2 in August 1994 indicate good water quality in the lower Little Blackfoot River.

At Clark Fork station 11, at Gold Creek Bridge, there were 11 dominant non-diatom taxa present, slightly fewer than was found upstream at Clark Fork station 10 and Little Blackfoot River station 10.2 (Figures 3 and 4). Additionally, the sensitive genera *Audouinella* and *Vaucheria,* both relatively important at station 10 and station 10.2, were absent at station 11. No dominant taxa representing phyla other than the green and blue-green algae were present at station 11 (Figure 4; Appendix A). The decrease in the number of dominant algal taxa, and the absence of some sensitive taxa at Clark Fork station 11 may indicate a decrease in water quality downstream of station 10. However, because approximately 10 stream miles separate the stations, it appears unlikely that the Little Blackfoot River could have had a negative impact on the Clark Fork at Gold Creek. Rather, the cause of any subtle impairment within this reach most likely could be found within the Clark Fork floodplain, such as stream channelization from past highway construction, or possibly another tributary stream. Low streamflows or elevated water temperatures may also have influenced the algae at station 11.

Nine dominant non-diatom taxa were identified in lower Flint Creek at station 11.5 (Figure 4), all of which were also present in the Little Blackfoot River and at Clark Fork stations 10 or 11 (Appendix A). The yellow-green genus *Vaucheria* was the most numerous non-diatom alga at station 11.5, followed closely by the blue-green alga *Nostoc*. *Cladophora* was the most important genus of green algae present, but as a phylum the Chlorophyta were somewhat less important than at the stations already discussed. In fact, the blue-green algae (phylum Cyanophyta) were dominant at station 11.5, based on total estimated biovolume relative to the other algal phyla present. Higher concentrations of phosphorus occur naturally in Flint Creek and other streams in the area that erode the Phosphoria Formation (Ingman et. al, 1979). Biologically available phosphorus may also enter Flint Creek from various sources related to human activities in the drainage. This may account for the increase in relative importance of the blue-green algae. Many blue-greens, including *Nostoc,* can fix atmospheric nitrogen and consequently are able to better utilize excess phosphorus when available nitrogen is limited.

Blue-green algae also were dominant at the two Clark Fork stations between Flint Creek and Rock Creek, as well as in Rock Creek itself, although the green algae continued to be well represented at all three locations (Table 3). Twelve dominant taxa were identified at Clark Fork station 11.7, at Bearmouth, while 10 genera were present at station 12, at Bonita (Figure 4). Stations 11.7 and 12 were very similar to one another in taxonomic makeup and in the relative importance of dominant taxa present at both sites (Appendix A). The red alga *Audouinella*, a rarity at station 11, again became relatively important, while *Cladophora* and *Nostoc* once again rounded out the top three non-diatom genera at both stations 11.7 and 12.

The top five non-diatom taxa identified in lower Rock Creek at station 12.5 are considered fairly sensitive forms, including the blue-green genera *Nostoc* and *Rivularia*, the filamentous green algae *Spirogyra* and *Cladophora*, and the uncommon brown alga (phylum Phaeophyta) *Heribaudiella*. The red algae *Audouinella* and *Lemanae* were present, but rare.

At Clark Fork station 13, located at Turah and several miles downstream of the Rock Creek confluence, there were 8 dominant non-diatom taxa identified, down slightly from the 10 genera present at station 12 (Figures 4 and 5). Station 13 had nearly the same dominant genera as Clark Fork station 12, with the exception of the genus *Audouinella*, which was rare at station 13 (Appendix A). These subtle changes in number and composition of dominant taxa suggest the periphyton at Clark Fork station 13 may have been slightly stressed. The high quality, although apparently somewhat different, water from Rock Creek may have affected

the stability at station 13. However, because of the distance between Rock Creek and station 13, it is also possible that any impact on the biota may have originated within the Clark Fork floodplain, possibly related to the low streamflows.

The lower Blackfoot River at station 14 had 11 dominant non-diatom algal genera present in August 1994 (Table 3; Figure 5). The dominant taxa identified in the Blackfoot River were almost identical to those found in Rock Creek on the same date, with one notable exception: the blue-green alga *Nostoc*, abundant in Rock Creek, was rare in the Blackfoot River (Appendix A). The near absence of *Nostoc* from station 14 reduced the importance of the blue-green algae relative to green algae, the latter of which consequently represented the dominant phylum in the Blackfoot River. But as was the case in Rock Creek, the non-diatom algae present in the Blackfoot River were indicative of generally good water quality.

Clark Fork station 15.5, below the Blackfoot River but above Missoula, had 13 dominant non-diatom genera present, which tied with Clark Fork station 10 for the most taxa present during the 1994 monitoring (Figures 3 and 5). Included at station 15.5 were most of the algal taxa present upstream at stations on both the Blackfoot River and the Clark Fork. Dominant green algae included the genus *Oedogonium,* which had been important only at Clark Fork stations above the Little Blackfoot River, and *Spirogyra*, a taxon dominant only in Rock Creek and the Blackfoot River. While present at station 15.5, the green alga *Cladophora* was considerably less important than at any of the Clark Fork stations upstream of the Blackfoot River. In addition to the aforementioned green algae, the blue-green genera *Nostoc, Oscillatoria* and *Phormidium,* and the red algae *Asterocystis* and *Audouinella* were among the dominant taxa present at station 15.5 (Appendix A). For the most part, these algae prefer cool, neutral pH water of good quality, with moderate levels of available inorganic nitrogen and phosphorus. The diverse algal assemblage at station 15.5 probably reflects relatively stable, low flow conditions in the Clark Fork above Missoula, with lower nutrient levels and temperature due to the influence of the Blackfoot River, and possibly also Milltown Dam and its small impoundment at the confluence of the Blackfoot River.

At Clark Fork station 18 at Shuffields, downstream from the Missoula municipal WWTP discharge, only 8 dominant non-diatom algal genera were present in mid-August 1994 (Figure 5). The taxa at station 18 had relatively little in common with those identified at Clark Fork station 15.5, with only 6 of the 13 dominant genera found upstream present below the WWTP. The green algae again were dominant at station 18, with the highly pollution-tolerant filamentous alga *Stigeoclonium*, and the less-tolerant *Cladophora*, ranked first and second, respectively, in biovolume relative to the total for non-diatom algae at station 18 (Appendix A). The ubiquitous blue-green alga *Phormidium* was very abundant, and ranked third in relative biovolume. Several relatively sensitive taxa important at station 15.5 were completely absent from Clark Fork station 18, including the genera *Oedogonium, Spirogyra, Nostoc* and *Audouinella*. The somewhat less-sensitive blue-green genus *Oscillatoria*, abundant at station 15.5, was all but gone from station 18 (Appendix A). It is highly probable that the complete disappearance of sensitive algal taxa, along with the appearance, or increase in abundance, of forms more tolerant of pollution, were in response to treated municipal wastewater discharged from Missoula's WWTP into the Clark Fork. These changes in the taxonomic makeup are evidence of water quality degradation at station 18, and indicate the biota there were under greater stress than at Clark Fork station 15.5 above Missoula. The effects of biogenic wastes, primarily incompletely-degraded organic nitrogen compounds, can include toxicity to sensitive organisms, a stimulatory effect on the growth of tolerant algae and bacteria, and a significant increase in instream oxygen demand. These impacts are particularly serious during periods of low streamflow, as was seen in 1994. It is also possible that unidentified pollution sources related to urbanization

might exist and contribute to water quality degradation in the Clark Fork reach through Missoula, although these sources probably would be relatively insignificant.

At station 19, Bitterroot River near its mouth, there were 10 dominant non-diatom genera present in August 1994 (Figure 5). Green algae once again comprised the dominant phylum, but only due to the sheer number of taxa present. Either of the familiar blue-greens *Oscillatoria* or *Phormidium* was more abundant than any one of the greens, and together accounted for more biovolume, relative to the total, than the top two genera of green algae (Appendix A). The list of green algae at Bitterroot River station 19 contains nearly all of the genera present at Clark Fork stations 15.5 and 18 (Appendix A). The filamentous green algae *Cladophora, Spirogyra* and *Stigeoclonium* all were present in about the same estimated relative abundance, while *Oedogonium* was slightly less abundant. No dominant genera representing a phylum other than the green and blue-green algae were present at station 19. The number of non-diatom taxa and the presence of relatively sensitive algae indicate generally good water quality in the Bitterroot River at station 19, although the relative importance of some tolerant green and blue-green genera, and the absence of sensitive phyla, may suggest at least a small degree of impairment.

Clark Fork station 20, at Harper Bridge, is about 8 miles downstream of the Bitterroot River confluence and roughly 12 stream miles below the Missoula WWTP discharge (Figure 1). There were 9 dominant non-diatom genera present at station 20, only one more than at station 18 (Table 3; Figures 5 and 6). Like station 18, *Cladophora, Stigeoclonium,* and *Phormidium* were the strongly dominant taxa at station 20, while more sensitive genera, including *Nostoc* and *Audouinella*, remained absent (Appendix A). *Oscillatoria*, a dominant taxon at Bitterroot River station 19, and last seen in the Clark Fork at station 15.5, once again was abundant at station 20. However, the overall status of the Clark Fork at station 20, compared to station 18, appears to have changed relatively little over the miles separating the two stations, even with the addition of the Bitterroot River.

Station 22, Clark Fork at Huson, is located approximately 10 miles downstream of station 20 and a few miles downstream of the Stone Container Corporation kraft mill, which discharges wastewater to the Clark Fork. Green algae dominated the 11 non-diatom taxa identified as common or greater in relative abundance at station 22 (Appendix A). The genus *Oedogonium*, last seen in the Clark Fork at station 15.5 above Missoula, was abundant at station 22, where it was surpassed only by *Cladophora* in estimated biovolume. *Stigeoclonium* remained a dominant taxon at station 22, although its abundance, in keeping with an apparent trend in the Clark Fork downstream of station 18, decreased slightly relative to the other algae present. The blue-green *Phormidium* remained abundant at station 22, while *Oscillatoria*, which had only returned to abundance at Harper Bridge, again became rare at Huson.

At least some degree of nutrient enrichment was indicated at the four stations between the Missoula WWTP and Huson, including the Bitterroot River, as evidenced by the increase in abundance of *Stigeoclonium*, and the corresponding decrease or outright disappearance of a number of more sensitive taxa. *Nostoc* and/or *Oscillatoria* were dominant taxa at most Clark Fork and tributary stations upstream of Missoula. However, *Nostoc* did not occur at stations 18, 19, 20 or 22, while *Oscillatoria* was rare at the two Clark Fork stations that most likely received the highest loads of treated municipal or industrial wastewater: stations 18 and 22, respectively. The low, stable streamflows, higher water temperatures, and relatively high nutrient concentrations all likely contributed to strong algal growth in 1994.

The three remaining Clark Fork stations are located at relatively long intervals along the lower river (Figure 1). Station 24, Clark Fork near Superior, is located some 45 stream miles below Huson, by far the longest

distance between mainstem Clark Fork stations in the study. The fact that several relatively major and numerous minor tributaries enter the Clark Fork in this reach serves to further distance station 24 from any factors affecting upstream Clark Fork stations. Eight dominant non-diatom taxa were identified near Superior, the fewest at any of the five stations below the Bitterroot River (Figure 6). The green algae, represented primarily by *Cladophora*, continued as the dominant phylum at station 24, although the blue-green algae were essentially co-dominant with the greens, as determined by the relative biovolume contribution estimated for each phylum. Ever-present *Phormidium* was very abundant at station 24, while for the first time downstream of Missoula, the more sensitive blue-green *Nostoc* returned as a dominant taxon. The tiny, epiphytic blue-green alga *Chamaesiphon* was often found in large numbers on *Cladophora* filaments throughout the Clark Fork basin. *Chamaesiphon* and the red alga *Asterocystis* were both abundant at station 24 (Appendix A). The algal assemblage at station 24 was not unlike those seen at Clark Fork stations upstream of Missoula, and suggests good water quality that is somewhat improved over that seen at stations 20 and 22.

Clark Fork station 25, above the Flathead River, is roughly 35 stream miles downstream of Superior. Again, numerous tributaries, including the Saint Regis River, enter the Clark Fork along this lengthy reach. *Chamaesiphon* was very abundant and, along with *Nostoc* and *Phormidium*, accounted for the blue-green algae becoming the dominant phylum at station 25. *Cladophora* remained at about the same relative abundance at station 25 as at station 24, but other green algae were slightly less important. The brown alga *Heribaudiella* and red alga *Audouinella*, both relatively sensitive genera, were common in the Clark Fork above the Flathead River. In addition to station 25, *Heribaudiella* was important in 1994 only at the Rock Creek and Blackfoot River stations upstream of Missoula, and was all but absent from the Clark Fork mainstem above station 25 (Appendix A). The algae present at station 25 continue to indicate relatively good water quality in the lower Clark Fork, and may suggest somewhat richer conditions than at station 24.

The lowermost station, Clark Fork above Thompson Falls Reservoir, station 27, is about 25 miles below the confluence of Flathead River (Figure 1). Because of the very large volume of water contributed to the Clark Fork by the Flathead River (the flow at station 27 is roughly double that at station 25), as well as inherent chemical and physical differences in waters from these drainages, some changes in the algal flora at station 27 from upstream Clark Fork stations should be expected. Technically, the green algae were the dominant phylum at station 27, due to the relatively large total biovolume of several common or very common taxa. However, co-dominance was more truly the case, as the blue-green genera *Chamaesiphon*, *Oscillatoria* and *Phormidium* were more numerous than any of the green algae, but together were responsible for a slightly smaller share of the estimated total algal biovolume present at station 27 (Appendix A). The sensitive brown alga *Heribaudiella* was more numerous at Clark Fork station 27 than at station 25, while the red algae were considerably less important.

All told, the non-diatom taxa at Clark Fork station 27, at least those along the shallow fringes of this very large river, indicate relatively good water quality. Interestingly, while *Oscillatoria* was very numerous at station 27, *Nostoc* was completely absent; the opposite occurred at stations 24 and 25. This relationship was also observed at other Clark Fork and tributary stations in 1994, and suggests that conditions favoring one blue-green taxon may exclude the other. *Nostoc* is known to have the ability to fix atmospheric nitrogen, and probably enjoys a competitive advantage where dissolved nitrogen compounds are limited relative to available phosphorus. Also, *Nostoc* is generally a cool water form, while *Oscillatoria* probably is tolerant of a wider range of temperatures. Water temperatures at station 27, below the Flathead River, were warmer than those upstream of the confluence, particularly with the low streamflow conditions experienced during August 1994.

Diatom Algae

The estimated abundance of diatoms (all genera considered collectively) relative to non-diatom algal genera at each of the 25 stations monitored in 1994 is included in Appendix A. Diatoms are also ranked with non-diatom algal genera according to the estimated contribution that they made, as a group, to the total periphyton biovolume in each sample (see Methods).

Diatoms were at least "very common" in estimated abundance, and therefore considered "dominant algae", at all 25 stations monitored in 1994 (Appendix A). They ranked first in estimated biovolume relative to non-diatom algae at 14 stations, second at 3 stations, third at 6 stations, and fourth at 2 stations (Appendix A).

All diatom species identified during floristic scans and proportional counts are listed alphabetically in Appendix B. Percent relative abundance (PRA) values that were calculated for diatom species counted in each sample are presented, by station, in Appendix B. Diatom species identified during the floristic scan, but not counted, are denoted with a "p", for "present". Lange-Bertalot pollution tolerance (PT) group assignments for each diatom species are also listed in Appendix B (see Methods).

Values for **diatom species richness** at each station monitored during 1994, along with the dominant diatom species and its corresponding PRA value, are listed in Table 3. The total percent relative abundance of diatom taxa in each of the three Lange-Bertalot pollution tolerance groups at each station are listed in Appendix B, and are plotted by station in Figures 7-11.

Values for the three diatom association metrics calculated for each station: the **Shannon diversity index, pollution index** and **siltation index**, are listed in Table 4, and are plotted in Figures 12-16, 17-21,and 22-26, respectively. All three metrics were used with bioassessment **Protocol I** to rate the **biological integrity** and **overall impairment** of aquatic life at each station, also listed in Table 4, according to criteria developed by Bahls (1993), with data from 21 least-impaired reference streams in Montana (Table 5).

Selected study sites on Silver Bow Creek and the Clark Fork were also rated for **biological integrity** and **overall impairment** of aquatic life according to bioassessment **Protocol II**, utilizing local reference sites for comparison (Tables 6-11), according to criteria presented in Table 12.

Diatom species richness values at all Clark Fork and tributary stations in 1994, with the exception of the three Silver Bow Creek stations upstream of the Warm Springs Ponds, were well within the range of 23-51 species established by Bahls et al. (1992) for least-impaired reference streams from mountain ecoregions (Table 3). Silver Bow Creek station 00, above the Butte Metro WWTP, had 21 diatom species present, compared to 42 species at station SF-1, Blacktail Creek above Grove Gulch, located a few miles upstream. At Silver Bow Creek station 01, below both the Colorado Tailings and Butte's WWTP discharge, only 14 diatom species were counted. At Silver Bow Creek station 2.5, some 15 miles downstream at Opportunity, only 13 diatom species were counted, the fewest at any station in 1994. Species richness rebounded significantly at Silver Bow Creek station 4.5, below the Warm Springs Ponds, where 38 diatom species were counted.

The highest Shannon diversity index (species diversity) value was found at Blacktail Creek station SF-1, while the three lowest values occurred at Silver Bow Creek stations 00, 01 and 2.5 (Table 4; Figure 12). Diatom species belonging to the most pollution-tolerant group (PT group 1) were strongly dominant at the three uppermost Silver Bow Creek stations (Figure 7), which resulted in the three lowest pollution index values seen in 1994 (Table 4; Figure 17). Silver Bow Creek station 01 below the Colorado Tailings, and below the Butte WWTP, had the

second lowest Shannon diversity index value, and the lowest pollution index value. Station 2.5 at Opportunity had the lowest species diversity value, and second lowest pollution index value of any station monitored in 1994.

Five of the highest siltation index values seen in 1994 occurred at the four Silver Bow Creek stations and in Blacktail Creek (Table 4; Figure 22), again recalling the that highest values indicate the worst siltation. Beginning with a moderately high value at Blacktail Creek station SF-1 above Grove Gulch, the siltation index steadily increased downstream to a maximum at Silver Bow Creek station 2.5 at Opportunity, then decreased slightly at station 4.5 downstream of the Warm Springs Ponds. Wide spread, naturally occurring sources of granitic sands in the Silver Bow Creek headwaters are likely sources of much of these sediments.

Both Blacktail Creek station SF-1 and Silver Bow Creek station 00 above the Butte Metro WWTP were rated as having only fair biological integrity, with moderate overall impairment of aquatic life under bioassessment Protocol I (Table 4). The moderately high siltation index values at both stations, and the low pollution index value at station 00, were to blame. At Blacktail Creek station SF-1, the dominant diatom taxon was *Nitzschia fonticola,* a pollution-sensitive form that prefers relatively low pH and dissolved solids, but is tolerant of siltation. At Silver Bow Creek station 00 above the Butte Metro WWTP, the dominant taxon was *Achnanthes minutissima*, a very ubiquitous PT group 3 diatom that requires fairly cool, well-oxygenated water, but is somewhat tolerant of disturbance and siltation. The low pollution index value for station 00 (Table 4) occurred despite a PRA of over 30 for *A. minutissima* (Table 3) due to a total PRA value for most-tolerant, PT group 1 diatoms of well over 50 (Figure 7; Appendix B). This suggests the biota at station 00 was under considerable stress, possibly due to the low streamflows, which may have been insufficient to flush accumulated sediment from the substrate.

Under bioassessment Protocol I, biological integrity at Silver Bow Creek stations 01, 2.5, and 4.5 was rated as poor, with severe impairment of aquatic life indicated (Table 4). Very low pollution index values and high values for siltation index were responsible for these ratings at Silver Bow Creek station 01 below the Colorado Tailings and the Butte Metro WWTP, and at station 2.5 at Opportunity. A high siltation index value was to blame for the poor rating at station 4.5 below the Warm Springs Ponds (Table 4). *Navicula minima*, a PT group 1 diatom that is highly tolerant of low dissolved oxygen as well as nutrient and sediment pollution, was strongly dominant at stations 01 and 2.5, with PRA values of around 50 at both stations (Table 3). The higher water temperatures and lower streamflows typically seen in mid-August, and particularly severe during a drought year like 1994, probably exacerbated the effects of Butte's wastewater discharge on Silver Bow Creek. Toxic metals contained within silt deposits may also have impacted the biota at the Silver Bow Creek stations downstream the Colorado Tailings. At station 4.5, below the Warm Springs Ponds, *N. minima* remained the dominant diatom taxon, but at a considerably lower PRA value of about 20 (Table 3). Also, the less-tolerant and sensitive diatom taxa, PT groups 2 and 3, respectively, increased significantly in PRA at Silver Bow Creek station 4.5 (Figure 7). This resulted in a considerable improvement in the pollution index compared to the Silver Bow Creek stations upstream of the Warm Springs Ponds (Table 4). Accumulated sediment, possibly due to the absence of flushing streamflows, and not toxic metals, would appear to have been largely responsible for the poor/severe ratings for biological integrity/overall impairment at Silver Bow Creek station 4.5. The poor/severe ratings at station 4.5 were not supported by either the diversity index or pollution index (Table 4). Channel reconstruction activities in the stream reach containing station 4.5 earlier in 1994 may have contributed to the sediment problem.

The four stations on Silver Bow Creek also were rated for biological integrity and overall impairment of aquatic life under bioassessment Protocol II, according to the criteria in Table 12, and utilizing Blacktail Creek station SF-1

(Table 6), and Warm Springs Creek station 06 (Table 7) as local reference sites. Blacktail Creek is a significant headwater tributary situated upstream of most historical disturbances and Superfund activities, and as such may resemble Silver Bow Creek prior to degradation, and serve as an approximation of the stream's potential. For this reason station SF-1 was chosen as a reference for the Silver Bow Creek sites despite ratings of fair/moderate for biological integrity/overall impairment under screening Protocol I. Warm Springs Creek station 06 was selected as a reference site based on its rating under Protocol I, which indicated excellent biological integrity, with no impairment of aquatic life, compared to 21 least-impaired reference streams in Montana. Warm Springs Creek was also utilized as a reference site to assess the biological integrity/overall impairment at Blacktail Creek station SF-1, as well as several other stations in 1994 (Table 7). Under Protocol II, Blacktail Creek station SF-1 received the same rating (fair/moderate) as it did under Protocol I (Table 7). All three Silver Bow Creek stations upstream of the Warm Springs Ponds were rated as having poor biological integrity, with severe impairment of aquatic life, when compared to either Blacktail Creek or Warm Springs Creek under Protocol II (Tables 6 and 7). When compared to the same reference sites, Silver Bow Creek station 4.5, below the Warm Springs Ponds, was rated as having fair biological integrity, with moderate impairment of aquatic life, an improvement over the Protocol I rating.

The dominant diatom taxon at Warm Springs Creek station 06 was *Cymbella affinis*, a cosmopolitan species that prefers slightly alkaline, moderately nutrient-rich water that is generally high in quality. As already mentioned, bioassessment Protocol I indicated no impairment of aquatic life in lower Warm Springs Creek, which had one of the highest pollution index values, and one of the lowest siltation index values seen in 1994 (Table 4).

Clark Fork station 07, below Warm Springs Creek, was rated as only fair for biological integrity, with moderate impairment of aquatic life under Protocol I (Table 4), as well as under Protocol II with Warm Springs Creek station 06 as the local reference site (Table 7). The moderately high siltation index at station 07 (Figure 23), apparently directly attributable to Silver Bow Creek station 4.5 upstream, was to blame for the moderate aquatic life impairment at station 07. *Nitzschia paleacea*, the dominant diatom taxon at Clark Fork station 07 below Warm Springs Creek, belongs to the less-tolerant PT group 2 taxa that, as a group, were relatively abundant at station 07 (Figure 8). However, the PRA of *N. paleacea* was quite low, and the Shannon diversity index high, which suggest that the level of stress on the biota at station 07 was not very high. In fact, when compared to the Little Blackfoot River station 10.2 under bioassessment Protocol II, Clark Fork station 07 was rated as having good biological integrity, with only minor impairment of aquatic life (Table 8). Keep in mind that when the Little Blackfoot River station 10.2 was compared to Warm Springs Creek station 06 under Protocol II, it was rated as having only fair biological integrity, with moderate impairment of aquatic life, due to a higher siltation index value and a low similarity index score (Table 7), but was rated as good/minor when compared to Rock Creek station 12.5 (Table 9).

Under Protocol I, Clark Fork station 09, at Deer Lodge, was rated as having good biological integrity, with only minor impairment of aquatic life, an improvement over Clark Fork station 07 that resulted from a significant decrease in the siltation index (Table 4; Figure 23). However, under Protocol II, with the Little Blackfoot River station 10.2 as the local reference site, the Clark Fork at station 09 was rated as having only fair biological integrity, with moderate impairment of aquatic life (Table 8). This apparent discrepancy was due to the relatively low similarity index value between the two stations; in reality, all three of the other diatom association metrics for station 09 had the highest possible scores of 4, when compared to the Little Blackfoot River (Table 8), and therefore do not seem to support the conclusion reached under Protocol II. The PT group 3 diatom *Achnanthes minutissima* was the dominant taxon at Clark Fork station 09. The moderately high PRA for *A. minutissima* of nearly 40 (Table 3) resulted in a slightly depressed Shannon diversity index value (Table 4;

Figure 13). This suggests that the biota at station 09 was under minor stress, possibly related to inorganic nutrient enrichment.

At Clark Fork station 10, above the Little Blackfoot River, biological integrity was rated as only fair under Protocol I, with moderate impairment of aquatic life indicated due to a moderately high siltation index value (Table 4; Figure 23). The pollution index value at station 10 was significantly lower than at Clark Fork station 09, and even slightly lower than at Clark Fork station 07 (Figure 18), in response to a lower total PRA of sensitive PT group 3 taxa, and a corresponding increase in less-tolerant PT group 2 diatoms (Figure 8). The dominant taxon at Clark Fork station 10, *Nitzschia inconspicua*, belonged to PT group 2, but had a PRA of only slightly over 12 (Table 3). Because no taxa were strongly dominant at station 10, the Shannon diversity index was well above 4 (Table 4; Figure 13), and did not suggest that the Clark Fork biota just upstream of the Little Blackfoot River was under a significant degree of stress. And when compared to the Little Blackfoot River itself under Protocol II, Clark Fork station 10 was rated as having good biological integrity, with only minor impairment of aquatic life indicated due to slightly dissimilar diatom floras (Table 8).

Little Blackfoot River station 10.2, near its mouth on the Clark Fork, was rated under bioassessment Protocol I as having good biological integrity, with minor impairment of aquatic life (Table 4). Under Protocol II with Warm Springs Creek station 06 as the local reference site, as was previously mentioned, the Little Blackfoot was rated as having only fair biological integrity, with moderate impairment of aquatic life due to low siltation and similarity index scores (Table 7). When Rock Creek station 12.5, near Clinton, was used as the local reference site, the ratings improved to good/minor for biological integrity/impairment of aquatic life, with only the slightly dissimilar diatom floras preventing the highest rating at station 10.2 (Table 9).

The next five stations on the Clark Fork mainstem: station 11, at Gold Creek; station 11.7, at Bonita; station 12, at Bearmouth; station 13, at Turah; and station 15.5, above Missoula, were rated under bioassessment Protocol I as having good biological integrity, with minor impairment of aquatic life (Table 4). At each station, the reason biological integrity was slightly less than the optimum expected, and overall impairment of aquatic life slightly greater than the optimum expected was the same: a slightly-to-moderately elevated value for the siltation index (Tables 4 and 5).

Clark Fork station 11 at Gold Creek was assessed under Protocol II using the Little Blackfoot River station 10.2 (Table 8) and Rock Creek station 12.5 (Table 9) as local reference sites. Both returned the same result as Protocol I: biological integrity at station 11 was good , with only minor impairment of aquatic life. However, the reason for the less-than-optimum integrity/impairment ratings was not the siltation index, but rather the slightly dissimilar diatom floras that resulted in similarity index scores of 3 for the study site, when compared to both reference sites. The dominant diatom taxon at station 11, *Epithemia sorex*, is known to harbor endophytic blue-green algae in a symbiotic relationship, and may enjoy an advantage over other diatoms due to the ability of the blue-greens to fix atmospheric nitrogen. *E. sorex* was the dominant taxon at all four Clark Fork stations in the reach between the Little Blackfoot and Blackfoot Rivers (Table 3).

Flint Creek station 11.5 at New Chicago was rated under Protocol I as having poor biological integrity, with severe impairment of aquatic life, due to a very high siltation index value (Table 4, Figure 24). Under Protocol II, with Warm Springs Creek station 06 as the local reference site,the biological integrity/overall impairment ratings for station 11.5 were fair/moderate, due to the very much higher siltation index value at station 11.5, and a very low similarity index value between the creeks (Table 7). Interestingly, comparisons between Flint Creek station 11.5, and both the Little Blackfoot River station

10.2 and Rock Creek station 12.5 under Protocol II returned much better ratings of good/minor for biological integrity/overall impairment of aquatic life for Flint Creek station 11.5. When the Little Blackfoot River was used as the reference site, only the percent similarity index scored less than the maximum of 4 (Table 8). With Rock Creek station 12.5 as the reference site, the pollution index, siltation index and similarity index all received scores of 3. The dominant taxon at Flint Creek station 11.5, *Navicula capitatoradiata*, is a PT group 2 diatom that tolerates higher levels of dissolved minerals, and moderate levels of organic (biogenic) nutrients. However, the PRA of *N. capitatoradiata* was relatively low, and the diversity index value at station 11.5 was the second highest seen in 1994 (Figure 14). As a comparison, the pollution index value at Flint Creek station 11.5 was only slightly lower than that at Little Blackfoot River station 10.2 (Table 4; Figure 18).

Clark Fork station 11.7, at Bonita, was also assessed under Protocol II using the Little Blackfoot River station 10.2 (Table 8) and Rock Creek station 12.5 (Table 9) as local reference sites. The comparison to Little Blackfoot River station 10.2 returned the same result as under Protocol I: biological integrity at Clark Fork station 11.7 was good, with only minor impairment of aquatic life at station 11.7. With Rock Creek station 12.5 as the reference site, the ratings for biological integrity/overall impairment at Clark Fork station 11.7 were fair/moderate, due only to the relatively dissimilar diatom floras at stations 11.7 and 12.5; the other three index ratios returned scores of 4 (Table 9). Any impairment to the biota at Clark Fork station 11.7 would seem to be relatively minor.

Clark Fork station 12 at Bearmouth was assessed under Protocol II using the Little Blackfoot River station 10.2 (Table 8), Rock Creek station 12.5 (Table 9), and as well as the Blackfoot River station 14 (Table 10) as local reference sites. With the Little Blackfoot River station 10.2 as the reference site, the same result was determined for Clark Fork station 12 as under Protocol I: biological integrity was good, with only minor impairment of aquatic life indicated. With Rock Creek station 12.5 as the local reference under Protocol II, biological integrity was rated fair, with moderate impairment at Clark Fork station 12, due only to the relatively dissimilar diatom floras at the two stations. Blackfoot River station 14 was rated under Protocol I as having excellent biological integrity, with no aquatic life impairment (Table 4). With Blackfoot River station 14 as the local reference site for Clark Fork station 12 under Protocol II, the rating for biological integrity again was only fair, with moderate impairment of aquatic life, again due to relatively dissimilar diatom floras at the two sites, and a considerably higher siltation index at Clark Fork station 12 (Table 10).

Rock Creek station 12.5, near Clinton, was rated under Protocol I as having good biological integrity, with minor impairment of aquatic life. The moderately elevated siltation index value was only to blame, as the diversity and pollution index values indicated no impairment at station 12.5 (Table 4). Under Protocol II, Rock Creek station 12.5 was used as a reference site, and therefore was not treated as a study site, per se. However, by calculating the inverse values of the diversity index, pollution index and siltation index ratios in Table 9, Rock Creek station 12.5 can be considered as a study site under Protocol II. Compared to the Little Blackfoot River station 10.2 and Flint Creek station 11.5, Rock Creek station 12.5 would be rated as having good biological integrity, with minor aquatic life impairment, due only to relatively low similarity index values. Because of a much higher siltation index value, as well as a low similarity index, Rock Creek station 12.5 would rate only fair for biological integrity, with moderate impairment of aquatic life, if compared to the Blackfoot River station 14 under Protocol II.

Clark Fork station 13, at Turah, is located downstream of the confluence of Rock Creek, but above the Blackfoot River (Figure 1). Under bioassessment Protocol I, Clark Fork station 13 was rated as having good biological integrity,

with minor impairment of aquatic life, due to a slightly elevated siltation index value (Table 4). Under Protocol II, with the Little Blackfoot River station 10.2 as the local reference site, biological integrity/overall impairment were also rated as good/minor, due to only slightly dissimilar diatom floras (Table 8). With Rock Creek station 12.5 as the reference site, Clark Fork station 13 was rated as having excellent biological integrity, with no impairment of aquatic life (Table 9). The high similarity index value suggests Rock Creek had considerable influence on the diatom flora at station 13, several miles downstream. Finally, with Blackfoot River station 14 as the reference site under Protocol II, Clark Fork station 13 was rated as having only fair biological integrity, with moderate impairment of aquatic life, due to low scores for the siltation index and similarity index (Table 10).

As was discussed previously, Blackfoot River station 14 was rated as having excellent biological integrity, with no impairment of aquatic life under Protocol I. Because it received such a high rating, the Blackfoot River was the logical choice as a local reference site for Protocol II assessments. It should be pointed out that the Blackfoot River did receive only fair/moderate ratings for biological integrity/overall impairment of aquatic life when compared to Rock Creek station 12.5, due only to a low similarity index value; ratios for the other three indexes indicated no impairment at station 14 (Table 9). Bitterroot River station 19 also was rated as having excellent biological integrity under Protocol I (Table 4). When the Blackfoot River was compared to the Bitterroot River (again, by calculating the inverse of index ratios listed for the Bitterroot River in table 10), the results were in agreement with the ratings for Blackfoot River station 14 under Protocol I. The dominant diatom species at station 14 was *Cymbella affinis*, a cosmopolitan PT group 3 taxon that prefers slightly alkaline, moderately nutrient-rich water. *C. affinis* was also the dominant diatom taxon in the lower Bitterroot River, and at all but the two lowermost Clark Fork stations downstream of station 14 (Table 3).

Clark Fork station 15.5 above Missoula, and downstream of the Blackfoot River, was rated as having good biological integrity under Protocol I, with only minor impairment of aquatic life, due a to moderately elevated siltation index value at station 15.5 (Table 4; Figure 25). Under Protocol II, with Blackfoot River station 14 as the local reference site, Clark Fork station 15.5 was rated as only fair for biological integrity, with moderate impairment of aquatic life, also due to the elevated siltation index value (Table 10). With the Bitterroot River station 19 as the reference site, the biological integrity/overall impairment ratings for Clark Fork station 15.5 were better, at good/minor, but continued to reflect a moderately higher siltation index value at station 15.5, and slightly dissimilar taxa between the stations (Table 11).

Clark Fork station 18 at Shuffields, and downstream of Missoula's municipal WWTP, was rated under bioassessment Protocol I as only fair for biological integrity, with moderate impairment of aquatic life, due to a high siltation index value (Table 4; Figure 25). Slightly lower diversity index and pollution index values at station 18 did not contribute to the low ratings for biological integrity/overall impairment at station 18, but do indicate that the biota was under a higher degree of stress than at Clark Fork station 15.5 above Missoula (Figures 15 and 20). Under Protocol II, with Blackfoot River station 14 as the reference site, biological integrity at station 18 was rated as poor, with severe impairment of aquatic life, due to the much higher siltation index value at station 18 (Table 10). When compared to Bitterroot River station 19 under Protocol II, the ratings improved slightly, to fair/moderate, with the high siltation index value at Clark Fork station 18 again the reason for the poorer ratings.

As was mentioned in the assessment of Blackfoot River station 14, Bitterroot River station 19 was rated under Protocol I as having excellent biological integrity, with no impairment of aquatic life (Table 4). Under Protocol II, with Blackfoot River station 14 as the local reference site,

Bitterroot River station 19 was rated as having good biological integrity, with minor impairment of aquatic life, and missed a rating of excellent by only a small margin due to a slightly higher siltation index value at station 19 (Table 10).

Clark Fork station 20 at Harper Bridge, and downstream of the Bitterroot River, was rated as having only fair biological integrity, with moderate impairment of aquatic life under Protocol I, due to a moderately high siltation index value at station 20 (Table 4; Figure 26). Under Protocol II, with both Blackfoot River station 14 (Table 10) and Bitterroot River station 19 (Table 11) as local reference sites, Clark Fork station 20 was rated as fair for biological integrity, with moderate impairment of aquatic life, which were in agreement with the Protocol I assessment of station 20. The diatom flora at Clark Fork station 20 was very similar to that at Bitterroot River station 19, but only slightly more so than to the flora at Blackfoot River station 14, based on the similarity index (Tables 10 and 11). At Clark Fork station 20, as was seen upstream at Clark Fork station 18, diversity index and pollution index values remained slightly depressed, indicating that minor stress on the biota continued downstream of Missoula (Table 4; Figures 16 and 21).

Clark Fork station 22 at Huson, and downstream of the Stone Container Corporation kraft mill, was rated as having good biological integrity, with minor impairment of aquatic life, under Protocol I (Table 4). The siltation index value at Clark Fork station 22, while still elevated, was considerably lower than was seen at upstream Clark Fork stations 18 and 20, and was nearly identical to the value for Clark Fork station 15.5 above Missoula (Figure 26). Diversity and pollution index values at Clark Fork station 22 were virtually unchanged from those seen at stations 18 and 20 (Figures 16 and 21). Under bioassessment Protocol II, with Blackfoot River station 14 as the reference site, Clark Fork station 22 was rated as having only fair biological integrity, with moderate impairment of aquatic life, again due to the higher siltation index (Table 10). With Bitterroot River station 19 as the local reference site under Protocol II, Clark Fork station 22 was rated as having good biological integrity, with only minor impairment of aquatic life, in agreement with the Protocol I ratings (Tables 4 and 11).

As was discussed in the non-diatom algae section, Clark Fork station 24 near Superior is a considerable distance downstream from Clark Fork station 22 at Huson, and is well removed from pollution sources and other factors potentially impacting the middle reach of the Clark Fork. Shannon diversity index and pollution index values at Clark Fork station 24 were moderately high, with very nearly the same values near Superior as were seen upstream at Clark Fork stations 13 at Turah, and 15.5 above Missoula (Table 4; Figures 16 and 21). The siltation index value at Clark Fork station 24 was actually lower than those seen at most upstream Clark Fork stations (Figure 26). Under Protocol I, biological integrity was rated as good, with only minor impairment at Clark Fork station 24, and missed an excellent rating by less than 1 siltation index unit. With Bitterroot River station 19 as the local reference site under Protocol II, Clark Fork station 24 again was rated as having good biological integrity, with only minor overall impairment of aquatic life (Table 11).

Clark Fork station 25 above the Flathead River was the only mainstem station in 1994 rated under Protocol I as having excellent biological integrity, with no impairment of aquatic life (Table 4). The excellent rating was given despite diversity index and pollution index values at station 25 that were slightly depressed compared to upstream Clark Fork stations (Table 4; Figures 16 and 21). The siltation index at station 25 was the lowest of any station in 1994 (Figure 26). Under Protocol II, with Bitterroot River station 19 as the only reference site, the biological integrity at Clark Fork station 25 was rated only fair, with moderate impairment of aquatic life, due to a relatively low similarity index value (Table 11). The dominant diatom species at station 25, and also at station 27, was *Cyclotella meneghiniana*. This cosmopolitan,

relatively pollution-tolerant, PT group 2 diatom can utilize organic nitrogen sources, and prefers moderately high levels of dissolved solids. The relatively high PRA of *C. meneghiniana*, along with the somewhat depressed diversity index, suggest that the biota at station 25 may have been under moderate stress, possibly due to low streamflow, higher water temperatures, and/or elevated organic (biogenic) nutrients. The biological integrity and overall impairment of aquatic life at Clark Fork station 25 may not deserve the high ratings given by Protocol I. It appears the considerably lower ratings generated by Protocol II, while based on a reference site that is not truly "local", may have been more realistic.

Clark Fork station 27 above Thompson Falls Reservoir, and downstream of the Flathead River, was rated as having good biological integrity, with only minor impairment of aquatic life under bioassessment Protocol I (Table 4). Because no reference site was available for this lowermost station on a now very large Clark Fork, Protocol II could not be not applied to station 27. The relatively low pollution index value (Figure 21) suggests somewhat lower water quality at Clark Fork station 27, although the moderately high diversity index (Figure 16), and the lower PRA of the dominant taxon do not indicate the same degree of stress on the biota as seen at Clark Fork station 25, upstream of the Flathead River. Low streamflows and higher water temperatures during 1994 may have stimulated heavy algal growth in the lower Clark Fork, resulting in the some degradation of water quality and the increase in pollution-tolerant taxa (Figure 11).

Figure 7.

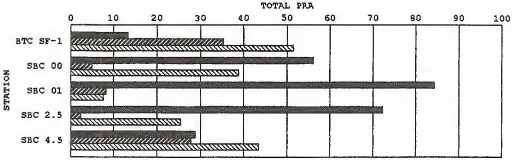


Figure 8.

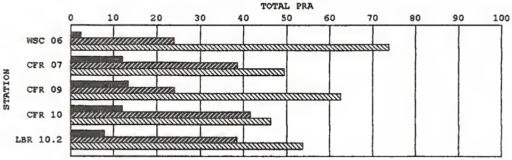


Figure 9.

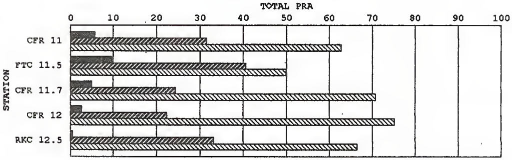


Figure 10.

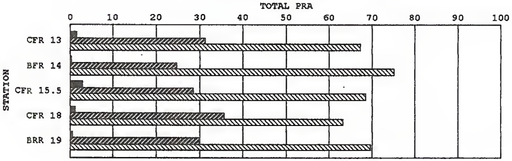
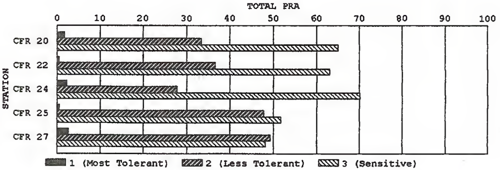


Figure 11.



Figures 7-11. Total percent relative abundance of diatom species in three pollution tolerance groups in diatom associations from the Clark Fork and tributaries during August 1994.

Figure 12.

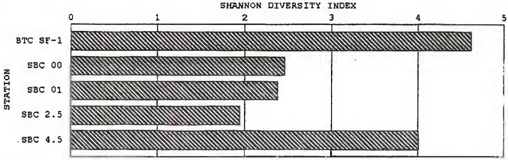


Figure 13.

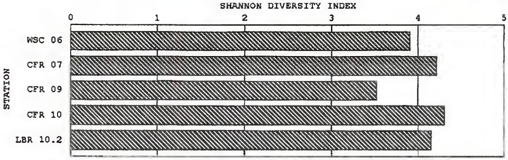


Figure 14.

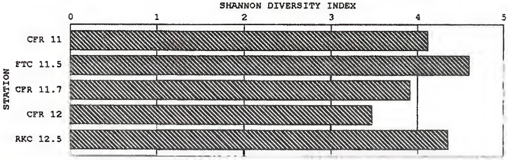


Figure 15.

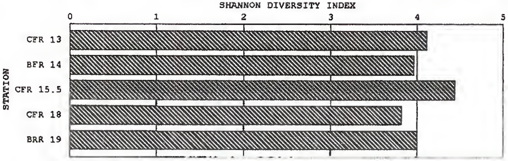
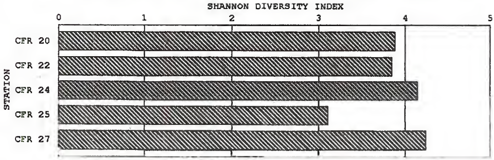


Figure 16.



Figures 12-16. Shannon diversity index values for diatom associations from the Clark Fork and tributaries during August 1994.

Figure 17.

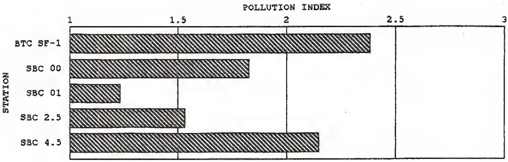


Figure 18.

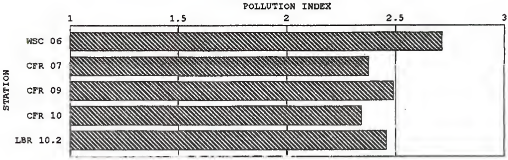


Figure 19.

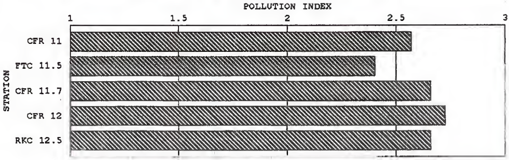


Figure 20.

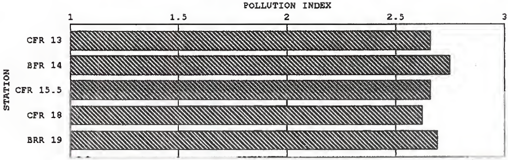
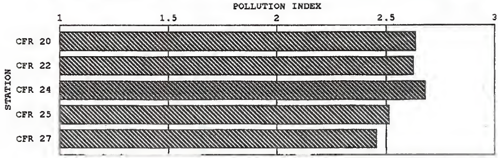


Figure 21.



Figures 17-21. Pollution index values for diatom associations from the Clark Fork and tributaries during August 1994.

Figure 22.

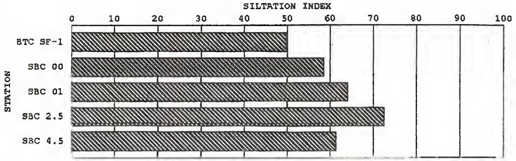


Figure 23.

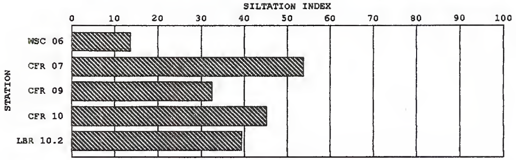


Figure 24.

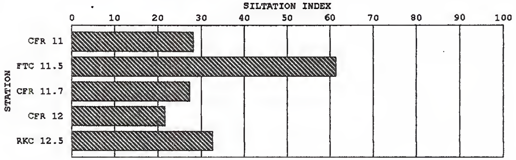


Figure 25.

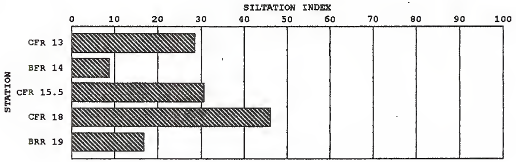
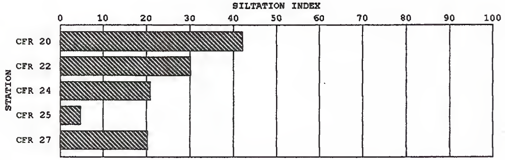


Figure 26.



Figures 22-26. Siltation index values for diatom associations from the Clark Fork and tributaries during August 1994.

Table 4. Diatom association metrics and biological integrity and overall impairment ratings[a] under bioassessment Protocol I for monitoring stations on the Clark Fork and tributaries during August 1994.

Station	Diversity Index	Pollution Index	Siltation Index	Biological[a] Integrity	Overall[a] Impairment
SF-1	4.62 (4)	2.38 (3)	49.75 (2)	fair	moderate
00	2.46 (3)	1.83 (2)	58.45 (2)	fair	moderate
01	2.38 (3)	1.23 (1)	64.00 (1)	poor	severe
2.5	1.94 (3)	1.53 (1)	72.43 (1)	poor	severe
4.5	4.00 (4)	2.15 (3)	61.35 (1)	poor	severe
06	3.91 (4)	2.71 (4)	13.64 (4)	excellent	none
07	4.21 (4)	2.37 (3)	53.72 (2)	fair	moderate
09	3.52 (4)	2.49 (3)	32.55 (3)	good	minor
10	4.31 (4)	2.34 (3)	45.13 (2)	fair	moderate
10.2	4.15 (4)	2.46 (3)	39.38 (3)	good	minor
11	4.11 (4)	2.57 (4)	28.23 (3)	good	minor
11.5	4.60 (4)	2.40 (3)	61.37 (1)	poor	severe
11.7	3.91 (4)	2.66 (4)	27.36 (3)	good	minor
12	3.47 (4)	2.72 (4)	21.62 (3)	good	minor
12.5	4.35 (4)	2.66 (4)	32.70 (3)	good	minor
13	4.11 (4)	2.66 (4)	28.57 (3)	good	minor
14	3.96 (4)	2.75 (4)	8.63 (4)	excellent	none
15.5	4.44 (4)	2.66 (4)	30.71 (3)	good	minor
18	3.82 (4)	2.62 (4)	46.08 (2)	fair	moderate
19	4.00 (4)	2.69 (4)	16.75 (4)	excellent	none
20	3.89 (4)	2.63 (4)	42.14 (2)	fair	moderate
22	3.84 (4)	2.63 (4)	30.05 (3)	good	minor
24	4.14 (4)	2.68 (4)	20.85 (3)	good	minor
25	3.11 (4)	2.51 (4)	4.77 (4)	excellent	none
27	4.24 (4)	2.45 (3)	20.24 (3)	good	minor

[a]Biological integrity and impairment ratings are based on scores in parentheses, according to criteria developed by Bahls (1993). See Table 5.

Table 5. Criteria for establishing impairment ratings and scores for diatom association metrics from mountain streams under bioassessment Protocol I (Bahls 1993).

Score	Rating	Diversity Index	Pollution Index	Siltation Index
1	high stress	<1.00		
	severe pollution		<1.50	
	heavy siltation			>60
2	moderate stress	1.00-1.75		
	moderate pollution		1.50-2.00	
	moderate siltation			40-60
3	minor stress	1.76-2.50		
	minor pollution		2.01-2.50	
	minor siltation			20-39
4	no stress	>2.50		
	no pollution		>2.50	
	no siltation			<20

Lowest Score	Biological Integrity	Overall Impairment
1	poor	severe
2	fair	moderate
3	good	minor
4	excellent	none

Tables 6 and 7. Ratings for biological integrity and overall impairment of aquatic life[a] at selected study sites on the Clark Fork and tributaries during August 1994, where a local reference site is available according to Bioassessment Protocol II (Bahls 1993).

Table 6.

Reference Site: **Blacktail Cr. SF-1** Study Sites:	**SBC 00**	**SBC 01**	**SBC 2.5**	**SBC 4.5**
Diversity Index Ratio (Score)	53%(2)	52%(2)	42%(2)	87%(4)
Pollution Index Ratio (Score)	77%(3)	52%(2)	64%(2)	90%(4)
Siltation Index Ratio (Score)	85%(4)	78%(4)	69%(4)	81%(4)
Similarity Index (Score)	16%(1)	16%(1)	12%(1)	34%(2)
Low Score	1	1	1	2
Biological Integrity[a]	**poor**	**poor**	**poor**	**fair**
Overall Impairment[a]	**severe**	**severe**	**severe**	**moderate**

Table 7.

Reference Site: **Warm Springs Cr. 06** Study Sites:	**BTC SF-1**	**SBC 00**	**SBC 01**	**SBC 2.5**
Diversity Index Ratio (Score)	118%(4)	63%(3)	61%(3)	49%(2)
Pollution Index Ratio (Score)	88%(3)	68%(2)	45%(1)	56%(2)
Siltation Index Ratio (Score)	27%(2)	23%(2)	21%(2)	18%(1)
Similarity Index (Score)	30%(2)	14%(1)	16%(1)	14%(1)
Low Score	2	1	1	1
Biological Integrity[a]	**fair**	**poor**	**poor**	**poor**
Overall Impairment[a]	**moderate**	**severe**	**severe**	**severe**

Reference Site: **Warm Springs Cr. 06** Study Sites:	**SBC 4.5**	**CFR 07**	**LBR 10.2**	**FTC 11.5**
Diversity Index Ratio (Score)	102%(4)	108%(4)	106%(4)	118%(4)
Pollution Index Ratio (Score)	79%(3)	87%(3)	91%(4)	89%(3)
Siltation Index Ratio (Score)	22%(2)	25%(2)	35%(2)	22%(2)
Similarity Index (Score)	20%(2)	32%(2)	25%(2)	30%(2)
Low Score	2	2	2	2
Biological Integrity[a]	**fair**	**fair**	**fair**	**fair**
Overall Impairment[a]	**moderate**	**moderate**	**moderate**	**moderate**

[a]Biological integrity and impairment ratings are based on scores in parentheses, according to criteria developed by Bahls (1993). See Table 12.

Table 8. Ratings for biological integrity and overall impairment of aquatic life[a] at selected study sites on the Clark Fork and tributaries during August 1994, where a local reference site is available according to Bioassessment Protocol II (Bahls 1993).

Reference Site: **L. Blackfoot R. 10.2** Study Sites:	**CFR 07**	**CFR 09**	**CFR 10**	**CFR 11**
Diversity Index Ratio (Score)	101%(4)	85%(4)	104%(4)	99%(4)
Pollution Index Ratio (Score)	96%(4)	101%(4)	95%(4)	104%(4)
Siltation Index Ratio (Score)	73%(4)	121%(4)	87%(4)	140%(4)
Similarity Index (Score)	41%(3)	25%(2)	48%(3)	59%(3)
Low Score	3	2	3	3
Biological Integrity[a]	**good**	**fair**	**good**	**good**
Overall Impairment[a]	**minor**	**moderate**	**minor**	**minor**

Reference Site: **L. Blackfoot R. 10.2** Study Sites:	**FTC 11.5**	**CFR 11.7**	**CFR 12**	**CFR 13**
Diversity Index Ratio (Score)	111%(4)	94%(4)	84%(4)	99%(4)
Pollution Index Ratio (Score)	98%(4)	108%(4)	111%(4)	108%(4)
Siltation Index Ratio (Score)	64%(4)	144%(4)	182%(4)	138%(4)
Similarity Index (Score)	50%(3)	53%(3)	58%(3)	56%(3)
Low Score	3	3	3	3
Biological Integrity[a]	**good**	**good**	**good**	**good**
Overall Impairment[a]	**minor**	**minor**	**minor**	**minor**

[a]Biological integrity and impairment ratings are based on scores in parentheses, according to criteria developed by Bahls (1993). See Table 12.

Table 9. Ratings for biological integrity and overall impairment of aquatic life[a] at selected study sites on the Clark Fork and tributaries during August 1994, where a local reference site is available according to Bioassessment Protocol II (Bahls 1993).

Reference Site: **Rock Creek 12.5** Study Sites:	**LBR 10.2**	**CFR 11**	**FTC 11.5**	**CFR 11.7**
Diversity Index Ratio (Score)	95%(4)	94%(4)	106%(4)	90%(4)
Pollution Index Ratio (Score)	92%(4)	97%(4)	90%(3)	100%(4)
Siltation Index Ratio (Score)	83%(4)	116%(4)	53%(3)	120%(4)
Similarity Index (Score)	53%(3)	42%(3)	41%(3)	39%(2)
Low Score	3	3	3	2
Biological Integrity[a]	**good**	**good**	**good**	**fair**
Overall Impairment[a]	**minor**	**minor**	**minor**	**moderate**

Reference Site: **Rock Creek 12.5** Study Sites:	**CFR 12**	**CFR 13**	**BFR 14**
Diversity Index Ratio (Score)	80%(3)	94%(4)	91%(4)
Pollution Index Ratio (Score)	102%(4)	100%(4)	103%(4)
Siltation Index Ratio (Score)	151%(4)	114%(4)	379%(4)
Similarity Index (Score)	41%(2)	63%(4)	36%(2)
Low Score	2	4	2
Biological Integrity[a]	**fair**	**excellent**	**fair**
Overall Impairment[a]	**moderate**	**none**	**moderate**

[a]Biological integrity and impairment ratings are based on scores in parentheses, according to criteria developed by Bahls (1993). See Table 12.

Table 10. Ratings for biological integrity and overall impairment of aquatic life[a] at selected study sites on the Clark Fork and tributaries during August 1994, where a local reference site is available according to Bioassessment Protocol II (Bahls 1993).

Reference Site: **Blackfoot R. 14** Study Sites:	**CFR 12**	**CFR 13**	**CFR 15.5**	**CFR 18**
Diversity Index Ratio (Score)	88%(4)	104%(4)	112%(4)	96%(4)
Pollution Index Ratio (Score)	99%(4)	97%(4)	97%(4)	95%(4)
Siltation Index Ratio (Score)	40%(2)	30%(2)	28%(2)	19%(1)
Similarity Index (Score)	24%(2)	37%(2)	56%(3)	47%(3)
Low Score	2	2	2	1
Biological Integrity[a]	**fair**	**fair**	**fair**	**poor**
Overall Impairment[a]	**moderate**	**moderate**	**moderate**	**severe**

Reference Site: **Blackfoot R. 14** Study Sites:	**BRR 19**	**CFR 20**	**CFR 22**
Diversity Index Ratio (Score)	101%(4)	98%(4)	97%(4)
Pollution Index Ratio (Score)	98%(4)	96%(4)	96%(4)
Siltation Index Ratio (Score)	52%(3)	20%(2)	29%(2)
Similarity Index (Score)	63%(4)	53%(3)	47%(3)
Low Score	3	2	2
Biological Integrity[a]	**good**	**fair**	**fair**
Overall Impairment[a]	**minor**	**moderate**	**moderate**

[a]Biological integrity and impairment ratings are based on scores in parentheses, according to criteria developed by Bahls (1993). See Table 12.

Table 11. Ratings for biological integrity and overall impairment of aquatic life[a] at selected study sites on the Clark Fork and tributaries during August 1994, where a local reference site is available according to Bioassessment Protocol II (Bahls 1993).

Reference Site: **Bitterroot R. 19** Study Sites:	**CFR 15.5**	**CFR 18**	**CFR 20**	**CFR 22**
Diversity Index Ratio (Score)	111%(4)	96%(4)	97%(4)	96%(4)
Pollution Index Ratio (Score)	99%(4)	98%(4)	98%(4)	98%(4)
Siltation Index Ratio (Score)	55%(3)	36%(2)	40%(2)	56%(3)
Similarity Index (Score)	51%(3)	53%(3)	61%(4)	68%(4)
Low Score	3	2	2	3
Biological Integrity[(a)]	**good**	**fair**	**fair**	**good**
Overall Impairment[(a)]	**minor**	**moderate**	**moderate**	**minor**

Reference Site: Bitterroot R. 19 Study Sites:	**CFR 24**	**CFR 25**
Diversity Index Ratio (Score)	104%(4)	78%(3)
Pollution Index Ratio (Score)	100%(4)	93%(4)
Siltation Index Ratio (Score)	80%(4)	351%(4)
Similarity Index (Score)	47%(3)	24%(2)
Low Score	3	2
Biological Integrity[(a)]	**good**	**fair**
Overall Impairment[(a)]	**minor**	**moderate**

[a]Biological integrity and impairment ratings are based on scores in parentheses, according to criteria developed by Bahls (1993). See Table 12.

Table 12. Criteria for establishing impairment ratings and scores for diatom association indexes when a local reference or control site is available and used under bioassessment Protocol II (Bahls 1993).

Score	Rating	Diversity Index[a]	Pollution Index[a]	Siltation Index[b]	Similarity Index[c]
1	high stress	<40 >160%			
	severe pollution		<50%		
	heavy siltation increase			<20%	
	very dissimilar communities				<20%
2	moderate stress	40-60% 140-160%			
	moderate pollution		50-70%		
	moderate siltation increase			20-40%	
	somewhat dissimilar communities				20-40%
3	minor stress	61-80% 120-139%			
	minor pollution		71-90%		
	small siltation increase			41-60%	
	somewhat similar communities				41-60%
4	no stress	>80% <120%			
	no pollution		>90%		
	no siltation increase			>60%	
	very similar communities				>60%

Lowest Score	Biological Integrity	Overall Impairment
1	poor	severe
2	fair	moderate
3	good	minor
4	excellent	none

[a]Value is ratio of study site index to reference site index X 100.

[b]Value is ratio of reference site index to study site index X 100.

[c]Percent community similarity index (Whittaker and Fairbanks 1958).

Trend Assessment

To assess general trends in water quality at Clark Fork and tributary stations, pollution index values for the last six monitoring years (1989-94) are plotted in Figures 27-31. Ratings for biological integrity and overall impairment of aquatic life for the years 1991-94, are presented in Table 15. It is difficult to measure the significance of apparent trends in these metrics. However, it should be noted that pollution index values are based on the pollution tolerances of many individual diatom species, while biological integrity and overall impairment ratings are determined under bioassessment Protocol I, utilizing three different diatom community-structure indexes. They therefore contain considerable environmental data in a condensed form. The following observations are based on Figures 27-30 and Table 13:

- Blacktail Creek above Grove Gulch, station SF-1, was monitored for the first time in 1993. Based on very similar pollution index values, water quality in Blacktail Creek was relatively good, and apparently quite stable during the very different water years 1993 and 1994. Biological integrity was rated slightly lower during 1994, a much below-average water year, than during 1993, a much above-average water year.

- Water quality at Silver Bow Creek station 00, above Butte's Wastewater Treatment Plant, appeared relatively stable over the period 1991-1994, but was significantly poorer during all four years than during the period 1989-91. Station 00 also had poorer water quality over the period 1993-1994 than did Blacktail Creek station SF-1 over the same two monitoring years. No clear trend was apparent in biological integrity at station 00, which continued to be fair-to-poor, with moderate-to-severe impairment of aquatic life.

- In 1994, only slight improvement in water quality was indicated at Silver Bow Creek station 01, below Butte's WWTP and the Colorado Tailings, following the very significant decline seen in 1993; pollution index values remained well below the levels seen over the period 1989-1992. Biological integrity at station 01, as in 1991 and 1993, was poor in 1994. Biological integrity at station 01 was rated as fair in 1992.

- A slight improvement in water quality was seen at Silver Bow Creek station 2.5 at Opportunity in 1994, following the decline noted in 1993. The pollution index at station 2.5 remained lower than during the period 1989-91, although the sampling location prior to 1993 was at a point downstream, and the new station 2.5 may not be entirely comparable to old station 03. Nevertheless, biological integrity remained poor at station 2.5, with severe impairment of aquatic life throughout the period of record.

- Water quality at Silver Bow Creek station 4.5 below the Warm Springs Ponds, as indicated by the pollution index, declined significantly in 1994 from the relatively high level seen in 1993. Pollution index values prior to 1993 also displayed large year to year variations. While significantly better than at Silver Bow Creek stations upstream of the ponds, water quality at station 4.5 continues to be quite variable. This is best illustrated by the poor biological integrity, and severe overall impairment of aquatic life ratings at station 4.5 in 1994, compared to the good integrity/minor impairment ratings in 1993.

- Warm Springs Creek station 06 continued to have high water quality in 1994, with a slight rebound in the pollution index that reversed a minor decline seen in 1993. Biological integrity was rated as excellent in 1994, with no impairment of aquatic life indicated, up from the good integrity/minor impairment rating received during the high streamflows in 1993. The trend over the period 1989-1996 has been one of steady improvement in water quality, followed by relative stability.

- In 1994, Clark Fork station 07 below Warm Springs Creek saw a significant drop in the pollution index to the 1992 level, reversing a five year trend of steady improvement in water quality. A decreased in biological integrity also was seen, to a rating of fair, following two years of good ratings. This decline at Clark Fork station 07 almost certainly was related to the more serious decline at Silver Bow Creek station 4.5, only a short distance upstream.

- The pollution index for Clark Fork station 09 at Deer Lodge increased slightly in 1994 and, while little change was seen the previous year, continued the trend begun in 1992 when the pollution index increased significantly. Biological integrity at station 09 also increased in 1994, to a rating of good, following two years of fair ratings and a poor rating in 1991. This suggests a strong trend of continued water quality improvement at station 09 at least since 1991 (Figure 28).

- The trend in water quality at Clark Fork station 10 above the Little Blackfoot River, clearly downward following the very high pollution index value in 1990, was reversed in 1994 suggesting a slight improvement in water quality. The ratings for biological integrity and overall impairment of aquatic life improved slightly in 1994 to fair/moderate following the poor/severe ratings seen in 1993.

- At Little Blackfoot River station 10.2, the pollution index decreased significantly in 1994 from a relatively high value recorded in 1993, the first year station 10.2 was monitored. However, biological integrity again was rated as good, with only minor impairment of aquatic life, suggesting water quality in the Little Blackfoot River remained relatively good in 1994 despite the low streamflow conditions.

- The pollution index at Clark Fork station 11, at Gold Creek Bridge, increased slightly in 1994 following the sharp decline in pollution index in 1993, but did not approach the very high levels seen during the period 1990-1992. The rating for biological integrity at station 11 did improve in 1994 to good, which suggests water quality was slightly improved.

- At Flint Creek station 11.5, at New Chicago, the pollution index value in 1994 was slightly lower than in 1993, the first year the station was monitored. Biological impairment also decreased, from fair in 1993 to a rating of poor in 1994.

- Clark Fork station 11.7 at Bearmouth, first monitored in 1993, had a somewhat higher pollution index rating in 1994. Biological integrity at station 11.7 was rated as good during both years, suggesting relatively high quality water in this reach of the Clark Fork.

- At station 12, Clark Fork at Bonita, the general downward trend evident in the pollution index over the previous two years was reversed by a relatively high pollution index value in 1994. And as was the case over the previous three years, biological integrity was rated good, with only minor overall impairment indicated, which suggests relatively stable conditions and good water quality at station 12.

- Rock Creek station 12.5 near the mouth was established in 1993. The pollution index value for 1994, while relatively high, was slightly lower than in 1993. Biological integrity was rated as good for both years, which suggests the water quality at station 12.5 was fairly high.

- At Clark Fork station 13, at Turah, pollution index values decreased very slightly in 1994, but biological integrity remained good, unchanged since 1991 when it was rated excellent. This suggests relatively stable conditions, with continued high quality water at station 13.

- Blackfoot River station 14 again had a very high pollution index value in 1994, almost exactly the same as was determined over the previous five years. The biological integrity rating at station 14 remained excellent, also was unchanged since 1991, with no aquatic life impairment indicated. Water quality remained very high.

- At Clark Fork station 15.5, above Missoula, the pollution index value decreased slightly in 1994, from a level nearly as high as seen in the Blackfoot River, and that had remained virtually constant since at least 1989. Biological integrity remained unchanged, however, with a rating of good, with only minor aquatic life impairment. This suggests water quality at station 15.5 continued to be very good in 1994.

- Clark Fork station 18, at Shuffields, saw a slight increase in the pollution index value in 1994, reversing the gradual downward trend evident since at least 1990. As in 1993, biological integrity, remained only fair at station 18, suggesting that water quality and aquatic life continued to suffer moderate impairment downstream of Missoula's municipal wastewater discharge.

- At Bitterroot River station 19, near the mouth, a fairly dramatic reversal of the strong five-year downward trend in the pollution index occurred in 1994, with the highest pollution index value seen over the six year period. Biological integrity, rated fair in 1991 and 1992, and only poor in 1993, increased to excellent in 1994. Significant improvement in water quality was suggested in the Bitterroot River in 1994.

- Clark Fork station 20 at Harper Bridge saw a slight drop in the pollution index value in 1994, continuing the trend that began in 1993. Biological integrity decreased to only fair in 1994 for the first time, following good ratings for three years running. Water quality apparently continued to decline at Clark Fork station 20 in 1994, despite improvements indicated in the Bitterroot River near its mouth on the Clark Fork, several miles upstream of the Harper Bridge station.

- Clark Fork station 22 at Huson saw a slight improvement in the pollution index in 1994, following a sharp drop in 1992, and a lesser decrease in 1993. The pollution index remained considerably lower than the very high values determined in 1990 and 1991. Biological integrity did increase from fair in 1993 to good in 1994, which also was the rating during both 1991 and 1992. The minor ratings for impairment of aquatic life at station 22 in 1991, 1992 and 1994 indicate that water quality remained relatively good at Huson during the low streamflow conditions seen during those years.

- At Clark Fork station 24 at Superior, the pollution index increased significantly in 1994, reversing the downward trend that began in 1992 and was particularly sharp in 1993. However, the pollution index value remained well below the peak value seen in 1991. Biological integrity improved to good in 1994, following a fair rating during the very high streamflows in 1993, which had dropped all the way from the excellent rating seen in 1992. All told, the water quality at station 24 appears to have been quite good from 1989 to 1994, as indicated by generally high pollution index values.

- The pollution index at Clark Fork station 25, above the Flathead River, dropped slightly during 1994 and, excepting a slight increase in 1993, continued a general downward trend that began in 1990. This trend is clearly contradicted by the biological integrity at station 25, which was rated as good in 1993, and as excellent during 1991, 1992 and again in 1994. What could be interpreted as declining water quality at station 25 does not appear to be causing any impairment of aquatic life.

- At Clark Fork station 27, above Thompson Falls Reservoir but downstream of the Flathead River, the pollution index decreased significantly in 1994 from the relatively high value seen in 1993. Compared to relatively stable pollution index values before 1992, the last three years have fluctuated greatly. However, the biological integrity remained excellent from 1991 to 1993, and only dropped to good during the very low streamflows that occurred in 1994, suggesting consistently good water quality at station 27.

Figure 27.

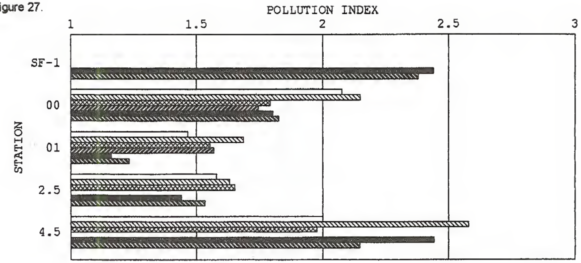


Figure 28.

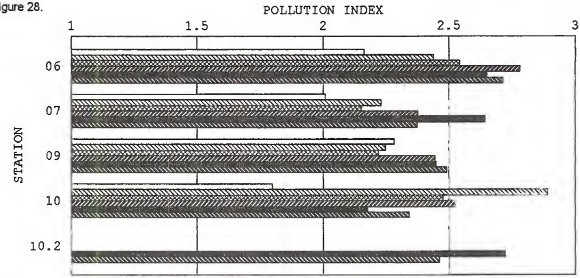
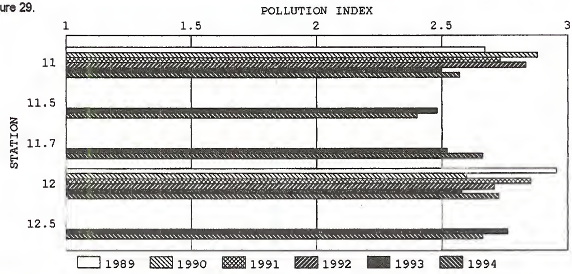


Figure 29.



Figures 27-29. Pollution index values from the Clark Fork and tributaries during August of six consecutive years, 1989-1994. Stations 03 and 04 were invalid in 1992, and were replaced in 1993 by stations 2.5 and 4.5, respectively. Stations SF-1, 10.2, 11.5, 11.7, and 12.5 were established in 1993.

Figure 30.

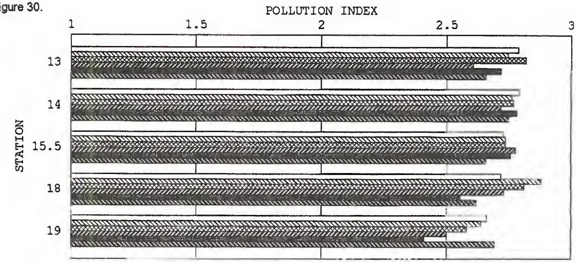
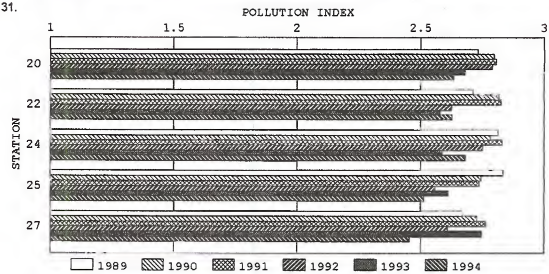


Figure 31.



Figures 30 and 31. Pollution index values from the Clark Fork and tributaries during August of six consecutive years, 1989-1994 (continued).

Table 13. Ratings for biological integrity and overall impairment of aquatic life at Clark Fork and tributary stations during August of four consecutive years, 1991-1994[a], based on bioassessment Protocol I. ns = not sampled

Station	1991		1992		1993		1994	
	Biological Integrity	Overall Impairment	Biological Integrity	Overall Impairment	Biological Integrity	Overall Impairment	Biological Integrity	Overall Impairment
SF-1	ns	ns	ns	ns	good	minor	fair	moderate
00	fair	moderate	poor	severe	poor	severe	fair	moderate
01	poor	severe	fair	moderate	poor	severe	poor	severe
2.5	poor	severe	ns	ns	poor	severe	poor	severe
4.5	poor	severe	ns	ns	good	minor	poor	severe
06	good	minor	excellent	none	good	minor	excellent	none
07	fair	moderate	good	minor	good	minor	fair	moderate
09	poor	severe	fair	moderate	fair	moderate	good	minor
10	fair	moderate	good	minor	poor	severe	fair	moderate
10.2	ns	ns	ns	ns	good	minor	good	minor
11	good	minor	excellent	none	fair	moderate	good	minor
11.5	ns	ns	ns	ns	fair	moderate	poor	severe
11.7	ns	ns	ns	ns	good	minor	good	minor
12	good	minor	good	minor	good	minor	good	minor
12.5	ns	ns	ns	ns	good	minor	good	minor
13	excellent	none	good	minor	good	minor	good	minor
14	excellent	none	excellent	none	excellent	none	excellent	none
15.5	good	minor	good	minor	good	minor	good	minor
18	good	minor	good	minor	fair	moderate	fair	moderate
19	fair	moderate	fair	moderate	poor	severe	excellent	none
20	good	minor	good	minor	good	minor	fair	moderate
22	good	minor	good	minor	fair	moderate	good	minor
24	good	minor	excellent	none	fair	moderate	good	minor
25	excellent	none	excellent	none	good	minor	excellent	none
27	excellent	none	excellent	none	excellent	none	good	minor

[a]Data for stations 2.5 and 4.5 during 1992 were invalid due to Superfund activities; stations 2.5 and 4.5 were known as 03 and 04 prior to 1993; Stations SF-1, 10.2, 11.5, 11.7 and 12.5 were established in 1993.

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APPENDIX A

Appendix A

Estimated relative abundance and biovolume contribution rank ( ) of diatoms and genera of non-diatom algae in periphyton samples from Clark Fork Basin biological monitoring, 1994.

R=rare; C=common; VC=very common; A=abundant; VA=very abundant

STREAM:	BTC	SBC	SBC	SBC	SBC
STATION NUMBER:	**SF-1**	**00**	**01**	**2.5**	**4.5**
SAMPLE NUMBER:	1398B	0847I	0102O	0245D	1399B
1994 SAMPLING DATE:	8/15	8/15	8/15	8/15	8/16
Bacillariophyta (diatoms)					
All genera collectively	VA(1)	VA(1)	VC(2)	VC(4)	A(3)
Chlorophyta (green algae)					
Ankistrodesmus	VC(11)	C(6)	R		
Cladophora	C(6)				VC(2)
Closterium	C(8)				R
Cosmarium	R	R		A(1)	C(8)
Gloeocystis	R	R	R	R	
Microspora	A(5)				R
Oedogonium	A(3)				VA(1)
Pediastrum	R		R		C(4)
Rhizoclonium	VC(4)	R			
Scenedesmus	VC(10)	C(5)	C(3)	VA(2)	C(7)
Spirogyra	C(7)				
Staurastrum	R				
Stigeoclonium		VC(3)	A(1)	R	R
Ulothrix	C(9)	A(2)			
Chrysophyta (yellow-green algae)					
Tribonema			R		
Vaucheria	A(2)				
Cyanophyta (blue-green algae)					
Chamaesiphon					C(9)
Lyngbya	R				
Nodularia	R				
Oscillatoria	R	VC(4)		VC(3)	C(6)
Phormidium				C(5)	VC(5)
Rhodophyta (red algae)					
Audouinella	R				

STATION NUMBER:	**SF-1**	**00**	**01**	**2.5**	**4.5**
TOTAL NON-DIATOM GENERA:	18	8	6	6	11
# DOMINANT GENERA:	10	5	2	4	8
# GREEN:	9	4	2	2	5
# BLUE-GREEN:	0	1	0	2	3
# OTHER:	1	0	0	0	0
DOMINANT PHYLUM:	Chlor	Chlor	Chlor	Chlor	Chlor

Appendix A

Estimated relative abundance and biovolume contribution rank ( ) of diatoms and genera of non-diatom algae in periphyton samples from Clark Fork Basin biological monitoring, 1994.
R=rare; C=common; VC=very common; A=abundant; VA=very abundant

STREAM:	WSC	CFR	CFR	CFR	LBR
STATION NUMBER:	06	07	09	10	10.2
SAMPLE NUMBER:	1020I	0849L	0266S	0850K	1400B
1994 SAMPLING DATE:	8/15	8/15	8/16	8/16	8/16
Bacillariophyta (diatoms)					
All genera collectively	VA(1)	A(3)	VA(1)	A(3)	A(4)
Chlorophyta (green algae)					
Ankistrodesmus	C(9)		VC(11)	A(7)	A(5)
Cladophora	R	VC(2)	VC(3)	VC(2)	
Closterium	C(7)				C(8)
Coelastrum					R
Cosmarium	R	R	R	R	C(11)
Gloeocystis			R	R	
Oedogonium	A(2)	VC(4)	VC(4)	C(9)	VC(3)
Pediastrum	VC(5)	C(6)	C(7)	C(11)	R
Scenedesmus	VC(6)	R	VC(8)	A(5)	VC(7)
Sphaerocystis	R				R
Staurastrum					C(12)
Stigeoclonium	R		A(6)	R	
Ulothrix	R				
Chrysophyta (yellow-green algae)					
Vaucheria				C(8)	VA(1)
Cyanophyta (blue-green algae)					
Calothrix				C(13)	
Chamaesiphon				C(14)	C(13)
Dichothrix				C(10)	R
Merismopedia	R				
Nostoc	A(3)	VA(1)	A(2)	VA(1)	VA(2)
Oscillatoria		R	C(10)	C(12)	
Phormidium	C(8)	VC(5)	VC(9)	A(6)	VC(10)
Tolypothrix		R			VC(6)
Rhodophyta (red algae)					
Asterocystis				R	R
Audouinella	A(4)	R	A(5)	VC(4)	C(9)

STATION NUMBER:	06	07	09	10	10.2
TOTAL NON-DIATOM GENERA:	14	10	12	17	17
# DOMINANT GENERA:	8	5	10	13	12
# GREEN:	5	3	6	5	6
# BLUE-GREEN:	2	2	3	6	4
# OTHER:	1	0	1	2	2
DOMINANT PHYLUM:	Chlor	Chlor	Chlor	Chlor	Chlor

Appendix A

Estimated relative abundance and biovolume contribution rank ( ) of diatoms and genera of non-diatom algae in periphyton samples from Clark Fork Basin biological monitoring, 1994.

R=rare; C=common; VC=very common; A=abundant; VA=very abundant

STREAM:	CFR	FTC	CFR	CFR	RKC
STATION NUMBER:	11	11.5	11.7	12	12.5
SAMPLE NUMBER:	0556K	1401B	0652C	0557K	1402B
1994 SAMPLING DATE:	8/16	8/16	8/17	8/17	8/17
Bacillariophyta (diatoms)					
All genera collectively	A(3)	VA(1)	VA(1)	VA(2)	VA(1)
Chlorophyta (green algae)					
Ankistrodesmus	A(5)	C(10)	VC(12)	VC(10)	VC(9)
Cladophora	VC(2)	VC(4)	VC(2)	A(3)	C(5)
Closterium	C(10)	C(7)	C(7)	C(8)	R
Coelastrum	R			R	
Cosmarium	C(8)		C(6)	C(7)	C(10)
Enteromorpha	C(9)				
Gloeocystis	R	R			
Gongrosira					R
Oedogonium		R			
Pediastrum	R		R	R	R
Scenedesmus	VC(6)	C(9)	C(11)	C(9)	R
Spirogyra					A(2)
Stigeoclonium	R	R	R	R	
Chrysophyta (yellow-green algae)					
Vaucheria		A(2)			
Cyanophyta (blue-green algae)					
Calothrix	VC(4)	VC(8)	VC(5)	VC(5)	R
Chamaesiphon	VC(12)		C(13)	C(11)	
Dichothrix	C(11)				
Merismopedia			VC(9)		
Microchaete					C(11)
Nostoc	VA(1)	A(3)	VA(3)	VA(1)	A(3)
Oscillatoria	R	VC(6)	C(10)	R	VC(7)
Phormidium	VC(7)	VA(5)	VC(8)	VC(6)	A(8)
Rivularia					A(4)
Tolypothrix	R				
Phaeophyta (brown algae)					
Heribaudiella					VC(6)
Rhodophyta (red algae)					
Asterocystis	R	R	R	R	
Audouinella	R	R	VC(4)	VC(4)	R
Lemanea					R

STATION NUMBER:	11	11.5	11.7	12	12.5
TOTAL NON-DIATOM GENERA:	19	14	15	15	17
# DOMINANT GENERA:	11	9	12	10	10
# GREEN:	6	4	5	5	4
# BLUE-GREEN:	5	4	6	4	5
# OTHER:	0	1	1	1	1
DOMINANT PHYLUM:	Chlor	Cyan	Cyan	Cyan	Cyan

Appendix A

Estimated relative abundance and biovolume contribution rank ( ) of diatoms and genera of non-diatom algae in periphyton samples from Clark Fork Basin biological monitoring, 1994.

R=rare; C=common; VC=very common; A=abundant; VA=very abundant

STREAM:	**CFR**	**BFR**	**CFR**	**CFR**	**BRR**
STATION NUMBER:	**13**	**14**	**15.5**	**18**	**19**
SAMPLE NUMBER:	0558Q	0752O	0897L	0676P	0278S
1994 SAMPLING DATE:	8/17	8/17	8/17	8/17	8/17
Bacillariophyta (diatoms)					
All genera collectively	VA(2)	VA(3)	VA(1)	VA(1)	VA(1)
Chlorophyta (green algae)					
Ankistrodesmus	VC(8)	A(7)	A(10)	A(7)	VC(10)
Chaetophora		R			
Cladophora	VC(3)	C(5)	C(6)	A(3)	VC(4)
Closterium	R	R	R	R	R
Coelastrum	C(9)	R	R	C(9)	C(11)
Cosmarium	VC(5)	C(10)	VC(9)	C(8)	VC(9)
Gloeocystis					R
Oedogonium	R		A(2)		C(8)
Pediastrum	R	C(9)	C(13)	R	R
Scenedesmus	VC(7)	VC(11)	VC(12)	VC(6)	VC(7)
Sorastrum					R
Spirogyra		VA(1)	A(3)		VC(5)
Staurastrum		R	R	R	R
Stigeoclonium	R	R	R	VA(2)	VC(6)
Cyanophyta (blue-green algae)					
Aphanocapsa				R	
Calothrix	R	C(8)	R		
Chamaesiphon			C(14)	R	
Nostoc	VA(1)	R	A(5)		
Oscillatoria		VA(2)	A(4)	R	A(2)
Phormidium	A(4)	VC(12)	A(8)	VA(4)	VA(3)
Rivularia	VC(6)	VC(6)			
Phaeophyta (brown algae)					
Heribaudiella	R	VC(4)			R
Rhodophyta (red algae)					
Asterocystis	R	R	VC(7)	VC(5)	
Audouinella	R	R	C(11)		

STATION NUMBER:	**13**	**14**	**15.5**	**18**	**19**
TOTAL NON-DIATOM GENERA:	16	19	18	14	16
# DOMINANT GENERA:	8	11	13	8	10
# GREEN:	5	6	7	6	8
# BLUE-GREEN:	3	4	4	1	2
# OTHER:	0	1	2	1	0
DOMINANT PHYLUM:	Cyan	Chlor	Chlor	Chlor	Chlor

Appendix A

Estimated relative abundance and biovolume contribution rank ( ) of diatoms and genera of non-diatom algae in periphyton samples from Clark Fork Basin biological monitoring, 1994.
R=rare; C=common; VC=very common; A=abundant; VA=very abundant

STREAM:	CFR	CFR	CFR	CFR	CFR
STATION NUMBER:	20	22	24	25	27
SAMPLE NUMBER:	0272T	0273Y	0901K	0903K	0905O
1994 SAMPLING DATE:	8/18	8/18	8/18	8/19	8/19
Bacillariophyta (diatoms)					
All genera collectively	VA(1)	VA(1)	VA(1)	VA(1)	A(3)
Chlorophyta (green algae)					
Ankistrodesmus	VC(7)	VC(9)	A(6)	VC(11)	VC(11)
Cladophora	VC(2)	VC(2)	VC(2)	VC(2)	VC(2)
Closterium	R	R		R	C(9)
Coelastrum	C(9)	C(10)	C(9)	R	R
Cosmarium	C(8)	R	R	R	VC(6)
Gloeocystis		R		R	
Mougeotia		C(6)			C(13)
Oedogonium		A(3)			
Pediastrum	R	C(8)	R	R	C(12)
Scenedesmus	VC(6)	VC(7)	VC(7)	VC(8)	VC(8)
Sphaerocystis	R				
Staurastrum	R				
Stigeoclonium	A(3)	VC(4)	R	R	R
Cyanophyta (blue-green algae)					
Calothrix				C(10)	
Chamaesiphon	C(10)	C(12)	A(8)	VA(5)	A(7)
Nostoc			VC(5)	C(6)	
Oscillatoria	A(5)	R	R		VA(1)
Phormidium	VA(4)	A(5)	VA(4)	VA(4)	VA(4)
Phaeophyta (brown algae)					
Heribaudiella				C(9)	VC(5)
Rhodophyta (red algae)					
Asterocystis	R	C(11)	A(3)	A(3)	C(10)
Audouinella				C(7)	

STATION NUMBER:	20	22	24	25	27
TOTAL NON-DIATOM GENERA:	14	15	12	16	14
# DOMINANT GENERA:	9	11	8	10	12
# GREEN:	6	8	4	3	7
# BLUE-GREEN:	3	2	3	4	3
# OTHER:	0	1	1	3	2
DOMINANT PHYLUM:	Chlor	Chlor	Chlor	Cyan	Chlor

APPENDIX B

Appendix B

Diatom proportional count data, Clark Fork Basin biological monitoring, August 15-19, 1994.
PT = Pollution Tolerance group number; PRA = Percent Relative Abundance. A letter "p" denotes species seen during floristic scan, but not during count.

STREAM:		BTC	SBC	SBC	SBC	SBC
STATION NO.:		SF-1	00	01	2.5	4.5
SAMPLE NO.:		1398B	0847I	0102O	0245D	1399B
1994 SAMPLING DATE:		8/15	8/15	8/15	8/15	8/16
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Achnanthes exigua	3	p				
Achnanthes lanceolata	2	9.75	0.68	0.71	0.47	0.24
Achnanthes minutissima	3	2.75	36.30	6.35	25.23	4.35
Amphora libyca	3	0.25		p		
Amphora pediculus	3	p	p	0.24	p	0.24
Amphora veneta	1	0.25				5.31
Anomoeoneis vitrea	2					p
Aulacoseira granulata	3					p
Caloneis bacillum	2	0.25	0.68		0.70	0.24
Caloneis silicua	2		p			p
Cocconeis pediculus	3	p			p	0.24
Cocconeis placentula	3	2.25	0.46	0.24	p	7.73
Cyclostephanos invisitatus	2	0.50				p
Cyclotella meneghiniana	2	3.25	0.23	0.24		0.24
Cymatopleura solea	2	p	p			
Cymbella affinis	3				p	
Cymbella silesiaca	3	10.25	0.46			0.24
Cymbella sinuata	3	0.25			p	0.24
Denticula kuetzingii	3					0.72
Denticula valida	3		p			
Diatoma mesodon	3				p	
Diatoma vulgaris	3		p	p		p
Epithemia sorex	3					2.66
Eunotia minor	3	p				
Fragilaria brevistriata	3	5.00	0.91			2.42
Fragilaria capucina	2	0.75	p	7.06	0.70	0.97
Fragilaria construens	3	1.00	0.46	p	p	9.18
Fragilaria crotonensis	3	0.75				
Fragilaria leptostauron	3		p			
Fragilaria nitzschioides	3			p	p	
Fragilaria parasitica	2					0.48
Fragilaria pinnata	3			p		p
Fragilaria ulna	2	0.75	0.23	p		p
Frustulia rhomboides	3	p				
Frustulia vulgaris	2	0.75				
Gomphoneis erlense	3				p	
Gomphonema acuminatum	3	p				
Gomphonema angustum	3		p		p	
Gomphonema clavatum	2	p				p
Gomphonema gracile	2		p			
Gomphonema minutum	3	5.75		p	p	
Gomphonema olivaceum	3		p			0.24
Gomphonema parvulum	1	2.75	1.14	21.18	0.47	0.97
Hannaea arcus	3				p	
Hantzschia amphioxys	2		p	p		
Melosira varians	2	3.00			p	p
Meridion circulare	3		p	p		
Navicula agrestis	1	0.25				
Navicula atomus	1	0.50	26.94	9.18	10.51	
Navicula bryophila	3					p
Navicula capitata	2		p			
Navicula capitatoradiata	2	2.25	p			

(continued) STREAM:		BTC	SBC	SBC	SBC	SBC
STATION NO.:		SF-1	00	01	2.5	4.5
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Navicula cryptocephala	3	1.75	p			0.97
Navicula cryptotenella	2	0.25				11.59
Navicula cryptotenelloides	1					0.24
Navicula decussis	3	2.25	0.23	0.71	p	0.24
Navicula gregaria	2	0.25	p			
Navicula halophilioides	1		p			
Navicula ignota	2	0.50	p	p		0.24
Navicula integra	2		p			
Navicula lanceolata	2	p	p			
Navicula libonensis	2		p			
Navicula lundii	2					0.24
Navicula menisculus	2	0.50				1.21
Navicula minima	1	4.50	21.92	46.35	53.27	20.53
Navicula minuscula	1	0.75	0.23	0.24	0.23	p
Navicula molestiformis	1	p				
Navicula mutica	2	p		p	0.23	
Navicula placentula	3	p				
Navicula pupula	2	1.75	p	p		
Navicula reichardtiana	2	p				
Navicula subhamulata	2					0.48
Navicula subminuscula	1	p				
Navicula tripunctata	3	1.50			p	p
Navicula trivialis	2	1.00	p	p	p	0.24
Navicula veneta	1		p			p
Navicula viridula	2		p			
Navicula wiesneri	1	p				
Neidium dubium	3					p
Nitzschia acicularis	2	5.00	0.23	p		p
Nitzschia amphibia	2	p	p			0.24
Nitzschia capitellata	2	p				
Nitzschia communis	1		p			
Nitzschia dissipata	3	3.50	p		0.23	2.42
Nitzschia draveillensis	1					1.21
Nitzschia fonticola	3	13.25	p			9.18
Nitzschia fossilis	2					0.24
Nitzschia hantzschiana	3	0.75	p			0.48
Nitzschia heufleriana	3	p				
Nitzschia inconspicua	2	3.25	0.23	0.24		4.59
Nitzschia linearis	2	1.50	p	p	p	p
Nitzschia palea	1	2.50	1.14	4.47	3.74	0.48
Nitzschia paleacea	2	p			p	6.52
Nitzschia perminuta	3	0.25				
Nitzschia pusilla	1	1.75	1.14	p		
Nitzschia sigmoidea	3					p
Nitzschia supralitorea	2	p				p
Nitzschia tubicola	1	p	p	p		
Pinnularia borealis	2				p	p
Pinnularia obscura	3			p	p	
Rhoicosphenia abbreviata	3	p	p		p	1.93
Stephanodiscus hantzschii	2	p	p	p		
Surirella angusta	1	p	3.65	2.82	3.97	
Surirella brebissonii	2		0.23			
Surirella minuta	2	p	2.51	p	0.23	

(continued) STREAM:	BTC	SBC	SBC	SBC	SBC
STATION NO.:	SF-1	00	01	2.5	4.5
Frustules Counted:	400	438	425	428	414
Total Species:	67	55	34	34	57
Species Counted:	42	21	14	13	38
Shannon Diversity:	4.62	2.46	2.38	1.94	4.00
Pollution Index:	2.38	1.83	1.23	1.53	2.15
Siltation Index:	49.75	58.45	64.00	72.43	61.35
Total PRA PT Group 1:	13.25	56.16	84.24	72.20	28.74
Total PRA PT Group 2:	35.25	5.02	8.24	2.34	27.78
Total PRA PT Group 3:	51.50	38.81	7.53	25.47	43.48

Appendix B
Diatom proportional count data, Clark Fork Basin biological monitoring, August 15-19, 1994.
PT = Pollution Tolerance group number; PRA = Percent Relative Abundance. A letter "p" denotes species seen during floristic scan, but not during count.

STREAM:		WSC	CFR	CFR	CFR	LBR
STATION NO.:		06	07	09	10	10.2
SAMPLE NO.:		1020I	0849L	0266S	0850K	1400B
1994 SAMPLING DATE:		8/15	8/15	8/16	8/16	8/16
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Achnanthes biasolettiana	3	p		0.24		
Achnanthes exigua	3			p		
Achnanthes lanceolata	2	p	0.72	p	0.48	1.43
Achnanthes lauenbergiana	2		p			
Achnanthes minutissima	3	10.77	5.76	38.68	1.90	0.24
Amphipleura pellucida	2					p
Amphora inariensis	3					0.24
Amphora libyca	3	p				
Amphora pediculus	3	p	0.48	0.47	7.13	2.39
Amphora veneta	1		4.08			
Anomoeoneis vitrea	2		p			
Aulacoseira distans	3					p
Aulacoseira granulata	3		0.24			
Caloneis bacillum	2	p	p	p	p	
Caloneis silicua	2	p				
Cocconeis pediculus	3	12.20	0.48			0.95
Cocconeis placentula	3	5.74	6.47	3.30	10.69	14.80
Cyclostephanos invisitatus	2	p		p	p	
Cyclotella distinguenda	2	0.24				
Cyclotella meneghiniana	2	0.48	0.48	0.94	7.60	13.84
Cymatopleura solea	2			0.24		
Cymbella affinis	3	19.38	2.64	0.24		
Cymbella cesatii	3	p				
Cymbella cistula	3	p				
Cymbella descripta	3	0.72	p			
Cymbella microcephala	2	0.72	p	p		
Cymbella minuta	2	0.24	p			
Cymbella reichardtii	3	p	0.24	p	0.95	p
Cymbella silesiaca	3	10.29	0.96	10.14	3.80	1.43
Cymbella sinuata	3	1.67	1.68	0.24	1.43	2.63
Cymbella subaequalis	3			p		
Denticula kuetzingii	3		p	p		
Diatoma mesodon	3	p	p			
Diatoma vulgaris	3	0.24	p	0.71	0.24	0.48
Epithemia sorex	3	p	0.48	p	4.51	11.93
Epithemia turgida	3					0.24
Fragilaria brevistriata	3	p	p	0.71		
Fragilaria capucina	2	14.35	1.92	0.47	0.48	0.72
Fragilaria construens	3	0.72	12.47	1.42	2.38	4.53
Fragilaria crotonensis	3	1.20				
Fragilaria leptostauron	3	1.44	p	0.47	0.24	0.72
Fragilaria nitzschioides	3					p
Fragilaria parasitica	2		0.48	0.24	p	
Fragilaria pinnata	3	0.72		0.24	0.48	0.48
Fragilaria ulna	2	0.48	1.68	3.54	0.95	0.48
Gomphoneis eriense	3					p
Gomphoneis minuta	3					p
Gomphonema angustum	3			0.24		
Gomphonema aquaemineralis	3	0.24		0.24	0.71	
Gomphonema clavatum	2	0.24	p	p	0.24	
Gomphonema dichotomum	3	p				
Gomphonema micropus	2		p		p	p

(continued) STREAM:		WSC	CFR	CFR	CFR	LBR
STATION NO.:		06	07	09	10	10.2
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Gomphonema minutum	3	0.24			p	0.24
Gomphonema olivaceum	3	p	0.24	0.47	0.48	0.48
Gomphonema parvulum	1	0.48	0.96	3.07	2.38	0.95
Gomphonema pumilum	3	1.44				
Melosira varians	2	2.15	p	p	p	0.95
Meridion circulare	3		p			
Navicula atomus	1		0.48	p	0.24	
Navicula capitatoradiata	2	1.20	1.92		p	7.16
Navicula cryptocephala	3	p	p			0.24
Navicula cryptotenella	2	1.67	13.67	2.83	8.79	1.19
Navicula decussis	3	p	0.24	0.24		
Navicula gregaria	2		p			
Navicula halophila	2			p		
Navicula heimansioides	2	p				
Navicula ignota	2		p	p	p	p
Navicula lanceolata	2				p	
Navicula libonensis	2	p			p	
Navicula lundii	2	p				
Navicula menisculus	2	0.24	0.48	p	p	p
Navicula minima	1		4.08	0.24	6.89	0.24
Navicula minuscula	1		p			p
Navicula oligotraphenta	3	p	0.24	p		
Navicula pupula	2	p	p	1.89	0.95	p
Navicula reichardtiana	2	0.24	p		p	3.82
Navicula stroemii	2	p				
Navicula tripunctata	3	2.39	3.12			1.91
Navicula trivialis	2		p			p
Navicula veneta	1		p		p	
Navicula wildii	2	p				
Neidium dubium	3			p	p	
Nitzschia acicularis	2			6.37	1.90	0.24
Nitzschia acidoclinata	3	0.24				
Nitzschia amphibia	2		0.72	0.47	0.48	
Nitzschia archibaldii	2	0.96		0.24		
Nitzschia capitellata	2		p	0.24	0.24	
Nitzschia dissipata	3	2.87	1.68	2.59	2.38	1.43
Nitzschia draveillensis	1	0.24	1.20			p
Nitzschia flexoides	2	p		p		
Nitzschia fonticola	3	0.96	8.15	0.71	0.48	5.25
Nitzschia hantzschiana	3	0.24	p	p		2.63
Nitzschia heufleriana	3			p	p	p
Nitzschia incognita	2			p	p	
Nitzschia inconspicua	2		2.40	1.42	12.35	1.67
Nitzschia intermedia	3				0.71	
Nitzschia linearis	2	p	p	3.54	1.66	p
Nitzschia palea	1	1.44	1.20	9.91	1.90	6.68
Nitzschia paleacea	2	0.72	13.91	1.42	5.46	6.92
Nitzschia perminuta	3	p	p			
Nitzschia pusilla	1	p	p			
Nitzschia semirobusta	2		0.24	0.24		
Nitzschia sigmoidea	3	p		p	p	p
Nitzschia supralitorea	2				p	p
Nitzschia umbonata	1			p	p	
Pinnularia microstauron	2			p		
Rhoicosphenia abbreviata	3	p	3.84	1.18	7.84	0.48
Rhopalodia gibba	2				p	
Simonsenia delognei	2				p	
Surirella angusta	1	0.24	p	0.24	0.71	
Surirella brebissonii	2			p		
Surirella minuta	2	p	p		p	

(continued) STREAM:	WSC	CFR	CFR	CFR	LBR
STATION NO.:	06	07	09	10	10.2
Frustules Counted:	418	417	424	421	419
Total Species:	69	66	63	57	52
Species Counted:	38	36	38	35	35
Shannon Diversity:	3.91	4.21	3.52	4.31	4.15
Pollution Index:	2.71	2.37	2.49	2.34	2.46
Siltation Index:	13.64	53.72	32.55	45.13	39.38
Total PRA PT Group 1:	2.39	11.99	13.44	12.11	7.88
Total PRA PT Group 2:	23.92	38.61	24.06	41.57	38.42
Total PRA PT Group 3:	73.68	49.40	62.50	46.32	53.70

Appendix B

Diatom proportional count data, Clark Fork Basin biological monitoring, August 15-19, 1994.
PT = Pollution Tolerance group number; PRA = Percent Relative Abundance. A letter "p" denotes species seen during floristic scan, but not during count.

	STREAM:	CFR	FTC	CFR	CFR	RKC
	STATION NO.:	11	11.5	11.7	12	12.5
	SAMPLE N0.:	0556K	1401B	0652C	0557K	1402B
	1994 SAMPLING DATE:	8/16	8/16	8/17	8/17	8/17

SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Achnanthes clevei	3					p
Achnanthes lanceolata	2	0.48	1.47	0.71	1.66	0.95
Achnanthes minutissima	3	1.20	1.47		p	2.63
Achnanthes peragalli	3					p
Amphipleura pellucida	2	p				
Amphora libyca	3	p				
Amphora pediculus	3	3.35	3.42	3.54	3.09	0.48
Caloneis bacillum	2	p		p	0.24	
Cocconeis pediculus	3	0.72	0.49	2.59	4.28	1.19
Cocconeis placentula	3	11.96	6.36	8.96	13.06	5.97
Cyclotella meneghiniana	2	6.70	2.44	4.01	4.75	0.48
Cymatopleura solea	2				p	
Cymbella affinis	3	0.24	3.67	1.18	p	p
Cymbella caespitosa	2					0.24
Cymbella elginensis	3					0.95
Cymbella mexicana	3					p
Cymbella microcephala	2					p
Cymbella minuta	2		0.24			3.82
Cymbella muelleri	2					p
Cymbella reichardtii	3	0.48		p		
Cymbella silesiaca	3	2.15	0.98	0.71	0.48	5.49
Cymbella sinuata	3	1.44	0.49	1.65	0.71	0.48
Diatoma mesodon	3					p
Diatoma vulgaris	3	1.44	0.24	1.18	0.95	0.24
Diploneis ovalis	2					p
Epithemia adnata	2	p				
Epithemia sorex	3	27.51	0.24	35.14	40.14	9.79
Epithemia turgida	3	0.48		p	0.24	3.82
Fragilaria brevistriata	3		p		p	
Fragilaria capucina	2	0.96	1.22	0.24	0.95	1.67
Fragilaria construens	3	2.15	3.91	2.83	4.28	14.08
Fragilaria crotonensis	3		p			
Fragilaria leptostauron	3	0.24	0.24	0.47	0.24	2.15
Fragilaria mazamaensis	3					0.48
Fragilaria parasitica	2		p	p		
Fragilaria pinnata	3	0.48	p	0.94	p	6.44
Fragilaria ulna	2	2.39	0.49	3.30	0.95	1.19
Gomphoneis eriense	3	p			p	0.24
Gomphoneis minuta	3					p
Gomphonema aquaemineralis	3	0.24		p		
Gomphonema clavatum	2	0.24		p	p	
Gomphonema micropus	2	0.24			p	
Gomphonema minutum	3		2.69	0.71	0.48	0.24
Gomphonema olivaceum	3	0.72	0.98	0.47	0.48	
Gomphonema parvulum	1	1.91	0.24	0.47	0.24	
Gomphonema pumilum	3			p		0.24
Gomphonema rhombicum	3					3.58
Gomphonema truncatum	3	p		0.24	p	
Gyrosigma acuminatum	3		p			
Melosira varians	2	0.48	0.98	0.94	0.24	
Meridion circulare	3		p			p
Navicula absoluta	3			p		

(continued) STREAM:		CFR	FTC	CFR	CFR	RKC
STATION NO.:		11	11.5	11.7	12	12.5
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Navicula atomus	1		p		p	
Navicula capitatoradiata	2	1.20	12.71	1.42	4.99	11.46
Navicula cryptocephala	3	p	p			p
Navicula cryptotenella	2	5.26	10.27	4.01	2.85	3.34
Navicula decussis	3	0.24		p	0.48	
Navicula detenta	3					0.24
Navicula gallica	2		p			
Navicula gregaria	2	p	p			
Navicula halophilioides	1		p	0.24		
Navicula ignota	2		0.24	p	p	
Navicula lanceolata	2	p	0.24	p	0.24	
Navicula libonensis	2		p			
Navicula menisculus	2		0.24	p		
Navicula minima	1	1.91	1.22	0.71	0.24	0.48
Navicula minuscula	1	p				
Navicula mutica	2	p				
Navicula oligotraphenta	3		p	p	p	
Navicula pupula	2	1.20	p	0.47	0.24	
Navicula radiosa	3					p
Navicula reichardtiana	2	0.72	2.20	1.65	0.95	3.34
Navicula stroemii	2				p	
Navicula tripunctata	3	0.48	4.65	0.47	p	0.48
Navicula trivialis	2		0.49	0.24	p	
Navicula veneta	1	p	p	0.24	p	
Neidium dubium	3	p		0.24	0.24	
Nitzschia acicularis	2	0.24	0.49			p
Nitzschia amphibia	2	0.24		p	0.24	
Nitzschia capitellata	2	p	0.73	p		
Nitzschia dissipata	3	1.91	6.85	5.19	4.28	0.95
Nitzschia fonticola	3	0.96	5.87	1.89	0.71	1.19
Nitzschia gracilis	2	0.24			p	
Nitzschia hantzschiana	3	0.72				4.53
Nitzschia heufleriana	3	p	0.24	0.24	0.24	p
Nitzschia inconspicua	2	7.42	1.71	5.19	2.38	1.67
Nitzschia intermedia	3	p	p			
Nitzschia linearis	2	0.24	2.69	0.24	p	
Nitzschia palea	1	1.91	4.65	2.36	1.43	p
Nitzschia paleacea	2	3.35	1.22	1.89	1.66	5.01
Nitzschia recta	3		0.49			
Nitzschia sigmoidea	3		0.24		p	
Nitzschia sociabilis	1		3.42	0.94	0.71	
Nitzschia supralitorea	2	p	p			
Nitzschia vermicularis	2		p		p	
Opephora olsenii	3			p	p	0.24
Rhoicosphenia abbreviata	3	3.59	6.36	2.12	0.71	0.24
Rhopalodia gibba	2	p		p	p	
Simonsenia delognei	2	p				
Surirella angusta	1	p		p		
Surirella brebissonii	2		p			
Surirella minuta	2	p	0.49	p	p	
Surirella ovalis	2		p			

(continued) STREAM:	CFR	FTC	CFR	CFR	RKC
STATION NO.:	11	11.5	11.7	12	12.5
Frustules Counted:	418	409	424	421	419
Total Species:	63	63	58	59	52
Species Counted:	42	43	39	36	37
Shannon Diversity:	4.11	4.60	3.91	3.47	4.35
Pollution Index:	2.57	2.40	2.66	2.72	2.66
Siltation Index:	28.23	61.37	27.36	21.62	32.70
Total PRA PT Group 1:	5.74	9.54	4.95	2.61	0.48
Total PRA PT Group 2:	31.58	40.59	24.29	22.33	33.17
Total PRA PT Group 3:	62.68	49.88	70.75	75.06	66.35

Appendix B

Diatom proportional count data, Clark Fork Basin biological monitoring, August 15-19, 1994.
PT = Pollution Tolerance group number; PRA = Percent Relative Abundance. A letter "p" denotes species seen during floristic scan, but not during count.

STREAM:		CFR	BFR	CFR	CFR	BRR
STATION NO.:		13	14	15.5	18	19
SAMPLE NO.:		0558Q	0752O	0897L	0676P	0278S
1994 SAMPLING DATE:		8/17	8/17	8/17	8/17	8/17
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Achnanthes biasolettiana	3		0.72	p	0.24	2.12
Achnanthes bioretii	3					p
Achnanthes clevei	3		p	p	p	p
Achnanthes exigua	3					0.24
Achnanthes hungarica	2	p				
Achnanthes lanceolata	2	0.97	p	p	0.48	2.12
Achnanthes laterostrata	3					p
Achnanthes minutissima	3	1.94	16.31	6.67	3.56	15.80
Achnanthes taeniata	3					0.24
Amphipleura pellucida	2		2.16	0.24	p	p
Amphora inariensis	3		p	p		
Amphora libyca	3	p				
Amphora ovalis	2					p
Amphora pediculus	3	0.24	1.44	0.71	0.71	0.71
Aulacoseira distans	3					p
Aulacoseira italica	3			p		
Caloneis bacillum	2		p		p	
Cocconeis pediculus	3	2.42	0.72	1.90	0.24	0.71
Cocconeis placentula	3	7.02	6.00	8.81	2.14	3.54
Cyclotella meneghiniana	2	4.36		2.86	2.38	p
Cymbella affinis	3	1.69	24.70	14.76	29.69	19.34
Cymbella caespitosa	2	p	0.24	0.95	p	
Cymbella cistula	3	p	p			p
Cymbella cymbiformis	3					0.24
Cymbella elginensis	3	0.24		p		p
Cymbella mexicana	3	p				
Cymbella microcephala	2		6.95	1.67	p	
Cymbella minuta	2	0.73	p	0.24	0.24	0.94
Cymbella muelleri	2			p		p
Cymbella silesiaca	3	0.97	1.44	0.24	0.48	1.42
Cymbella sinuata	3	1.21	1.20	0.71	0.95	1.18
Cymbella tumida	3				p	0.24
Cymbella turgidula	3					3.07
Denticula tenuis	3		p	p		
Diatoma mesodon	3			p		
Diatoma tenuis	2			0.24		
Diatoma vulgaris	3	3.39	p	1.19	3.56	6.13
Epithemia adnata	2		0.24			
Epithemia sorex	3	22.76	0.48	6.19	1.43	0.24
Epithemia turgida	3	p	1.68		p	
Fragilaria brevistriata	3	0.48				p
Fragilaria capucina	2	p	3.36	0.95	0.48	0.71
Fragilaria construens	3	11.38	6.95	9.52	0.71	1.42
Fragilaria leptostauron	3	0.97	2.40	0.48	0.24	p
Fragilaria mazamaensis	3	p	0.48	p		p
Fragilaria parasitica	2				p	
Fragilaria pinnata	3	1.21	2.16	0.95	0.71	0.47
Fragilaria ulna	2	5.33	6.00	3.33	1.90	14.39
Gomphoneis eriense	3		p	p		0.24
Gomphoneis minuta	3		p			0.71
Gomphonema acuminatum	3			p		
Gomphonema aquaemineralis	3	p				p

(continued) STREAM:		CFR	BFR	CFR	CFR	BRR
STATION NO.:		13	14	15.5	18	19
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Gomphonema clavatum	2	p	0.24		p	
Gomphonema dichotomum	3			p		p
Gomphonema micropus	2		p	p		
Gomphonema minutum	3	1.45	2.16	1.67	1.19	2.12
Gomphonema olivaceum	3	0.48	0.48	1.43	p	
Gomphonema parvulum	1	p	p	p	0.48	p
Gomphonema pumilum	3		2.64	0.95	0.48	4.01
Gomphonema rhombicum	3	0.24	p		p	p
Gomphonema truncatum	3					p
Hannaea arcus	3			p		
Melosira varians	2	p		p	0.71	
Meridion circulare	3			0.24		
Navicula accomoda	1				p	
Navicula atomus	1				p	
Navicula bacillum	3			p		
Navicula bryophila	3			p		
Navicula capitatoradiata	2	12.35	2.16	7.86	12.59	5.90
Navicula cryptocephala	3				p	p
Navicula cryptotenella	2	1.94	1.68	4.05	3.80	2.36
Navicula decussis	3			p		p
Navicula elginensis	3		p			
Navicula ignota	2	0.24	p			p
Navicula lanceolata	2	p		0.48	p	
Navicula libonensis	2				p	
Navicula lundii	2		p			
Navicula menisculus	2	p	p		p	0.24
Navicula minima	1			0.24		p
Navicula minuscula	1		p			
Navicula oligotraphenta	3		p	p		
Navicula perminuta	2					0.24
Navicula pseudanglica	2			p		
Navicula pupula	2			0.24	p	
Navicula radiosa	3			p	p	
Navicula reichardtiana	2	1.69	0.72	0.95	0.71	0.24
Navicula subminuscula	1				p	
Navicula tripunctata	3	0.48	0.48	1.19	1.90	0.24
Navicula veneta	1			p		
Navicula viridula	2		p			
Neidium dubium	3	p	p	p		
Nitzschia acicularis	2	0.24				
Nitzschia amphibia	2	p		p	4.51	
Nitzschia archibaldii	2			p		
Nitzschia bacillum	3		0.24			
Nitzschia capitellata	2	p				
Nitzschia dissipata	3	1.45	1.20	7.14	2.61	0.24
Nitzschia fonticola	3	0.97	0.72	0.71	10.45	4.01
Nitzschia gracilis	2	0.24			p	
Nitzschia hantzschiana	3	4.36	0.24	0.71	0.95	p
Nitzschia heufleriana	3			p	p	
Nitzschia inconspicua	2	1.94		1.67	0.95	1.18
Nitzschia lacuum	3		0.24	p		
Nitzschia linearis	2	0.24		0.24	p	
Nitzschia palea	1	1.45	0.24	2.62	0.71	0.47
Nitzschia paleacea	2	0.97	p	1.90	6.89	1.65
Nitzschia perminuta	3	p		p		
Nitzschia pura	2		p			
Nitzschia radicula	2		0.24		p	
Nitzschia recta	3			p		
Nitzschia supralitorea	2		0.48		p	

(continued) STREAM:		CFR	BFR	CFR	CFR	BRR
STATION NO.:		13	14	15.5	18	19
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Opephora olsenii	3					0.94
Opephora pacifica	3	0.48		p		
Pinnularia microstauron	2			p		
Rhoicosphenia abbreviata	3	1.45	p	2.38	0.95	p
Rhopalodia gibba	2		0.24			p
Surirella angusta	1	p		p		
Surirella minuta	2			0.71		
Frustules Counted:		413	417	420	421	424
Total Species:		56	61	74	59	62
Species Counted:		37	37	40	34	37
Shannon Diversity:		4.11	3.96	4.44	3.82	4.00
Pollution Index:		2.66	2.75	2.66	2.62	2.69
Siltation Index:		28.57	8.63	30.71	46.08	16.75
Total PRA PT Group 1:		1.45	0.24	2.86	1.19	0.47
Total PRA PT Group 2:		31.23	24.70	28.57	35.63	29.95
Total PRA PT Group 3:		67.31	75.06	68.57	63.18	69.58

Appendix B

Diatom proportional count data, Clark Fork Basin biological monitoring, August 15-19, 1994.
PT = Pollution Tolerance group number; PRA = Percent Relative Abundance. A letter "p" denotes species seen during floristic scan, but not during count.

STREAM:		**CFR**	**CFR**	**CFR**	**CFR**	**CFR**
STATION NO.:		**20**	**22**	**24**	**25**	**27**
SAMPLE NO.:		0272T	0273Y	0910K	0903K	0905O
1994 SAMPLING DATE:		8/18	8/18	8/18	8/19	8/19
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Achnanthes biasolettiana	3	0.48	0.48	0.24	p	0.95
Achnanthes clevei	3	p	0.72	p		0.24
Achnanthes exigua	3	p	p	p		
Achnanthes hungarica	2				p	
Achnanthes lanceolata	2	0.48	0.24	0.71	0.24	0.71
Achnanthes laterostrata	3	p				
Achnanthes minutissima	3	3.10	3.13	3.08	1.43	4.52
Amphipleura pellucida	2					p
Amphora libyca	3	p	p			
Amphora pediculus	3	0.24	0.48	1.42	1.19	1.43
Anomoeoneis vitrea	2					p
Aulacoseira granulata	3					p
Cocconeis neodiminuta	3					p
Cocconeis pediculus	3	2.14	1.68	10.43	4.30	1.90
Cocconeis placentula	3	3.57	4.33	12.32	15.51	7.86
Cyclostephanos invisitatus	2			0.24	p	2.14
Cyclotella comensis	3					p
Cyclotella meneghiniana	2	0.95	2.40	11.14	42.48	29.52
Cyclotella ocellata	3					p
Cyclotella pseudostelligera	2					p
Cymbella affinis	3	26.43	19.95	16.82	4.30	4.05
Cymbella caespitosa	2	p		p	p	p
Cymbella delicatula	3					p
Cymbella microcephala	2	p	p	p		1.67
Cymbella minuta	2	p	0.24	0.24	p	p
Cymbella naviculiformis	3					p
Cymbella silesiaca	3	0.48	0.24	p	0.48	p
Cymbella sinuata	3	0.95	0.96	3.08	3.58	3.10
Cymbella tumida	3	p				
Cymbella turgidula	3		p			
Denticula tenuis	3			p		
Diatoma vulgaris	3	4.52	14.90	0.24	p	1.67
Epithemia adnata	2	p			p	p
Epithemia sorex	3	0.48	0.24	5.92	8.59	2.62
Epithemia turgida	3			0.47	0.72	0.24
Fragilaria brevistriata	3		p	p		0.24
Fragilaria capucina	2	1.19	p		0.72	2.38
Fragilaria construens	3	2.86	1.44	2.84	5.73	5.95
Fragilaria leptostauron	3	p	0.48	0.95	0.48	1.67
Fragilaria nanana	3					0.24
Fragilaria pinnata	3	0.24	0.24	0.95	0.48	1.67
Fragilaria robusta	3			p		
Fragilaria ulna	2	5.48	12.50	0.95	1.19	2.86
Gomphoneis eriense	3					p
Gomphoneis minuta	3	0.24				
Gomphonema clavatum	2	p	p	p		p
Gomphonema dichotomum	3			p		p
Gomphonema minutum	3	3.33	2.40	4.50	1.91	1.19
Gomphonema olivaceum	3	p		p	p	p
Gomphonema parvulum	1	0.24	0.24	0.24	p	p
Gomphonema pumilum	3	0.24	0.48	p	0.72	p
Gomphonema rhombicum	3				0.24	

(continued) STREAM:		CFR	CFR	CFR	CFR	CFR
STATION NO.:		20	22	24	25	27
SPECIES	PT	PRA	PRA	PRA	PRA	PRA
Gomphonema truncatum	3	p	p			
Melosira varians	2	p	0.72	p		
Meridion circulare	3		p			
Navicula bacillum	3		p			
Navicula capitata	2	p		p		
Navicula capitatoradiata	2	12.38	13.70	5.21	0.95	2.86
Navicula cryptocephala	3		p			
Navicula cryptotenella	2	5.48	3.61	3.32	p	2.14
Navicula decussis	3	0.24	0.24		p	p
Navicula gastrum	2					p
Navicula gregaria	2	p				
Navicula ignota	2	0.24		p	p	0.24
Navicula lanceolata	2			p		
Navicula libonensis	2	p				
Navicula lundii	2					p
Navicula menisculus	2	p	0.24	0.24		
Navicula minima	1		p	0.24		
Navicula muraloides	3					p
Navicula perminuta	2	0.24	p	p		p
Navicula pupula	2		p	p	p	
Navicula radiosa	3					p
Navicula reichardtiana	2	0.24		0.24	0.24	0.71
Navicula tripunctata	3	3.10	4.09	1.90	0.48	0.95
Nitzschia acicularis	2			0.47	0.24	0.24
Nitzschia amphibia	2	0.95	0.48	p		
Nitzschia archibaldii	2		0.24	0.47		0.24
Nitzschia dissipata	3	0.71	0.48	p	p	3.81
Nitzschia draveillensis	1					0.24
Nitzschia fonticola	3	10.48	4.09	1.90	0.48	1.67
Nitzschia hantzschiana	3	0.95	0.48	0.71	0.24	0.71
Nitzschia inconspicua	2	0.71	0.24	1.90	p	0.95
Nitzschia lacuum	3					0.95
Nitzschia linearis	2				p	p
Nitzschia palea	1	1.43	0.24	1.66	0.48	2.38
Nitzschia paleacea	2	5.00	1.92	2.61	1.67	1.90
Nitzschia perminuta	3					p
Nitzschia radicula	2					0.24
Nitzschia sinuata	1					p
Opephora olsenii	3		p	0.47	0.48	p
Rhoicosphenia abbreviata	3	0.24	1.44	1.90	0.48	0.48
Thalassiosira pseudonana	2					0.48

	CFR 20	CFR 22	CFR 24	CFR 25	CFR 27
Frustules Counted:	420	416	422	419	420
Total Species:	53	51	55	45	70
Species Counted:	35	36	35	29	41
Shannon Diversity:	3.89	3.84	4.14	3.11	4.24
Pollution Index:	2.63	2.63	2.68	2.51	2.45
Siltation Index:	42.14	30.05	20.85	4.77	20.24
Total PRA PT Group 1:	1.67	0.48	2.13	0.48	2.62
Total PRA PT Group 2:	33.33	36.54	27.73	47.73	49.29
Total PRA PT Group 3:	65.00	62.98	70.14	51.79	48.10